Electrochemical Industry

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ADVERTISING RATES GIVEN ON APPLICATION.

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Editorial 385
Society of Chemical Industry 388
The Chemistry of Electroplating. By W. D. Bancroft 389
Differences in the Electrolysis of Potassium and Sodium Chloride. By F. Winteler 391
Electrolysis and Catalysis. By W. Ostwald 393
The Manufacture of Ferro-Alloys in the Electric Furnace. By G. P. Scholl 395
Electrochemistry at the International Electrical Congress of St. Louis 397
T. W. Richards on the Relation of the Hypothesis of Compressible Atoms to Electrochemistry 397
J. S. Edstrom on Electrical Extraction of Nitrogen from the Air 399
F. Haber and L. Bruner on the Carbon Cell 401
L. Kahlenberg on the Electrochemical Series of Metals 402
A. G. Betts and E. F. Kern on the Lead Voltameter 403
J. Swinburne on Chlorine in Metallurgy 404
H. Goldschmidt on Aluminothermics 404
K. E. Guthe on the Silver Voltameter 406
H. S. Carhart and G. A. Hulett on Materials for Standard Cells 407
P. L. T. Héroult on Electrometallurgy of Iron and Steel 408
A. E. Kennelly and S. E. Whiting on the Edison Storage Battery 409
J. W. Richards on Electrolytic Conduction 411
R. Lorenz on Electrolysis of Fused Salts 412
H. E. Patten on Deposition of Aluminium from Ethyl Bromide Solutions 413
W. D. Bancroft on Aluminium Rectifiers 413
W. McA. Johnson on Some Aspects of Applied Electrochemistry 414
F. A. J. FitzGerald on Testing the Temperature in Electric Furnaces 415
W. D. Bancroft on Electrolytic Separation of Cobalt and Nickel 415
Notes on Papers on Electrochemical Subjects before other Sections of the Congress 416
New York Meeting of the Society of Chemical Industry 417
Sir William Ramsay on the Training of Technical Chemists 417
Chamber of Delegates, International Electrical Congress, St. Louis, 1904 419
Cost of Electric Power Used in Electric Reduction Works. By Louis Simpson 421
Correspondence: Solubility of Gold. By C. J. Reed 422
Analysis of Current Electrochemical Patents. By George P. Scholl. 423
Synopsis of Articles in Other Journals 426
Recent Metallurgical Patents 429
Book Reviews: Classen, Quantitative Chemical Analysis by Electrolysis 431
Pyrometers Suitable for Metallurgical Work 431
Suction Gas Producers 432
Industrial Notes 433
Personal 434
Digest of United States Patents, Prior to July, 1902. By Byrnes & Townsend (Electrolysis of Molten Sodium Salts; Molten Electrolytes, Miscellaneous) 434

ELECTROCHEMISTRY AT THE INTERNATIONAL ELECTRICAL CONGRESS OF ST. LOUIS.

The Electrical Congress, held at St. Louis from September 12 to 17, was the fifth of international electrical congresses, but it was the first one of such bodies at which electrochemistry was adequately represented. It is not that electrochemical engineering is so young that it could not have been represented as such on former congresses—storage battery engineering and electrolytic copper refining are as old as dynamo construction. But in the past the engineers and scientists working in the field of electrochemistry were scattered, and, in this country at least, electrochemistry as an organized profession, with a fully developed esprit de corps, dates only from the organization of the American Electrochemical Society. The great success of the St. Louis Congress in general—which surpassed all former electrical congresses by the number of those who enrolled as members, by the number of those who attended it, and by the number of excellent papers presented—this success is due largely to the splendid and careful work of the Organization Committee and its indefatigable chief officers, Prof. Elihu Thomson, Dr. A. E. Kennelly and Mr. W. D. Weaver, and to the shrewd policy by which all the national electrical engineering societies of this country were enlisted as co-workers for the success of the Congress. To the co-operation of the American Electrochemical Society is largely due the success of the electrochemical section of the Congress. As was already noticed in these columns, the American Electrochemical Society decided to hold its regular autumn meeting in connection with the Congress, but to hold only one independent session, and to spend all surplus energy to further the success of Section C of the Congress. Thus, there was a most intimate connection between Section C and the American Electrochemical Society; only somebody most thoroughly initiated would have been able to tell at any moment whether he was attending a meeting of Section C or of the Society or a joint meeting. Under these circumstances we have thought it best to give a full account of the doings of both Section C and of the Society in one single report under the title Electrochemistry at the International Congress of St. Louis. This report will be found on other pages of this issue.

The way in which electrochemistry was represented, was most gratifying. Section C was one of the most international sections of the Congress. Of course Americans largely prevailed among the authors of papers, but there were also represented Germany, France, England, Sweden and Switzerland. Moreover, the programme was well-balanced, the numbers of engineering and scientific papers being about equal. This was due to the fact that the Congress papers were specially invited from authors in many countries, instead of being volunteered from members of a national society only. The fact

that the Congress was held in a World's Fair city, had both advantages and disadvantages. Undoubtedly, many were thereby induced to attend the Congress, who would have hesitated otherwise. On the other hand, many who pretended to have come to attend the Congress were rather visitors at the Fair. One of the worst disadvantages was the location of the Congress headquarters in the business district in the southern part of the city, while the Fair is held in the far northwest; traveling to and fro in a crowded street car is anything but delightful. The counter attractions afforded by the Fair and by the other sections of the Congress, caused the attendance in any single section to be less than is usual in meetings of our national engineering societies. This was the same in Section C, as in all other sections. The only session of Section C which drew a large audience was the special session, at which Dr. H. Goldschmidt delivered his lecture on aluminothermics; but this session was held in a hall on the Exposition grounds, and during evening hours, when there were no other section meetings. While the relatively small attendance at the various sessions impaired somewhat the value of the discussions, yet the work and the importance of the Congress is rather determined by the value of the papers themselves which were presented. There can be no doubt that in this respect the Congress was an even greater success than its most enthusiastic promoters had anticipated.

Among the papers on industrial electrochemistry and electrometallurgy, Dr. P. L. T. Héroult's paper on the use of the electric furnace in the iron and steel industries deserves the full interest of both manufacturers and users of steel. Dr. Héroult refers briefly to the reduction of iron ores in the electric furnace, but the main point of the paper is his advocacy of the electric furnace for steel refining, as an adjunct to existing steel plants; he claims that at a cost of not more than 50 cents per ton, any steel, delivered in molten state, such as tapped out of a Siemens furnace or obtained from a Bessemer converter, can be converted into steel of any desired composition, containing not more than 0.01 sulphur and 0.01 phosphorus. It is to be taken into consideration that it is Dr. Héroult who makes this claim, and that he makes it on the basis of his experience obtained in two years' working of his process on a commercial scale. The conclusion which he draws is obvious; it is that while the electric furnace may not revolutionize the metallurgy of iron and steel, yet it will so cheapen the production of those at present very expensive finest grades of steel that they will come into more and more extended use in the near future. Dr. Hans Goldschmidt's lecture on aluminothermics did not reveal any new principles of his well-known method, but many details on the increasing use of this method in various industries, of which the applications of the box reaction in foundry practice are most interesting; a promising new development for various chemical industries is the treatment of the aluminium oxide slag with a binding material for the manufacture of chemical apparatus and vessels with practically zero coefficient of expansion.

Mr. J. S. Edstrom's paper brought a subject to the front which has attracted many inventors in recent years—the fixation of atmospheric nitrogen. The feature of the process of Birkeland and Eyde, described by Mr. Edstrom, is that in the rapid production and interruption of arcs passing through the air to be acted upon, the familiar phenomenon of the deviation of the arc by a magnetic field is made use of. The chief advantages claimed for this method are that one is not restricted in the amount of electric power used and that the wear and tear of the apparatus is small. Some details in Mr. Edstrom's paper are very interesting, but the information given is not yet sufficient to form a conclusive idea on the economy of the operation of the process. Mr. James Swinburne's paper on chlorine smelting records an interesting application of the non-electrochemical part of his process by the (British) Castner-Kellner Company. Of course, the purpose of this company is to make good use of their electrolytic chlorine; they could, therefore, not use the Swinburne process as a whole in which the chlorine passes through a cycle, and in which no new chlorine is required, except for making up the unavoidable losses. They therefore stop with the production of zinc chloride, which is sold.

Prof. A. E. Kennelly and Prof. S. E. Whiting presented, in behalf of Mr. T. A. Edison, a paper giving the results obtained with his nickel-iron storage battery up to the present date. The point emphasized by the authors is that in the Edison battery we have for the first time a steel structure for an electrolytic process which, with respect to the figure of watts per pound, is comparable to the steel structure of dynamos. A very interesting paper by Mr. F. A. J. FitzGerald dealt with the use of samples of carbon for determining the temperature within an electric furnace; this method is based on the fact that the determination of the density of carbon can be used for estimating the temperature to which it was subjected. By placing a number of samples of carbon at different points within a furnace, it is thus possible to find whether the distribution of the temperature throughout the furnace is as desired; for instance, whether it is uniform, if this is wanted. It becomes more and more necessary to use all possible skill in the design of electrical furnaces in order to utilize them to the best advantage, and a simple means, like that of Mr. FitzGerald, to find out whether a furnace design is what it is intended to be, should be most valuable. A paper of Mr. W. McA. Johnson gave interesting general points of view on industrial electrochemistry; any engineering process is intended—in the last resort—to make as much money as possible, and any electrochemical method, if used as part of a chain of metallurgical operations, should be so devised that the efficiency of the whole chain is a maximum.

Among the purely scientific papers, one by Prof. T. W. Richards gives a very interesting outline of the very wide field of electrochemical and electrical phenomena, to which the view point of his hypothesis of compressible atoms may advantageously be applied, although it is avowedly still nothing more but a hypothesis. A paper by Dr. Louis Kahlenberg gives interesting results on very extended experimental researches on potential differences of metals in various solvents, the main point being the proof that a slight change in the composition of the solvent may change the order of the metals in the electrochemical series. The importance of the

establishment of these experimental results will not be denied by anybody, though it may be doubted that they refute the fundamental assumptions of Nernst's theory of solution tension, as Dr. Kahlenberg appears to assume. It is true that the solution tension of a metal has often been assumed to be independent of the solvent, but there is no necessity for such an assumption, if one critically reviews the thermodynamical reasoning on which Nernst's formula, containing the solution tension, is based. In a paper on the mechanism of the conduction of an electric current through electrolytes Dr. J. W. Richards offers a thesis which is radically different from the views generally held. He suggests that the conduction of the current through the interior of an electrolyte is not different from the conduction of the current through a metal and that this conduction should be carefully differentiated from the chemical phenomena of oxidation and reduction, taking place at the electrodes. There was a lively discussion of this paper and the experiment quoted by the author as confirmation of his theory was not considered as convincing. However, any theory is in reality nothing but a description of facts, and if Dr. Richards could develop his theory, so that it fully describes all the facts, it would be just as good as the model of ions. But it seems rather doubtful whether the theory could be so developed as to cover, for instance, Kohlrausch's law of the independent movement of the ions in very dilute solutions, which represents an experimental fact and is very easily described by the model of ions.

Of the papers on the border line between electrochemical science and industry, those of Prof. W. Ostwald on electrolysis and catalysis, and Prof. W. D. Bancroft on the chemistry of electroplating, were specially interesting, and are, for this reason, printed in full in this issue. But both papers are markedly different from each other in one respect. In Prof. Ostwald's paper we are confronted rather with a theory, than with a condition; he gives a theory of what might be done, and, perhaps, will be done; the paper is certainly highly suggestive. In the case of electroplating we are confronted by a condition—a mass of experimental facts, found in the practical working of many years by the cut-and-try method—while a theory which combines all these single facts is missing. Prof. Bancroft made the praiseworthy attempt to lay the keystones of such a theory. Prof. F. Haber and Dr. L. Bruner gave a new theory on the action of the Jacques carbon cell; while the explanation given by the authors is absolutely novel, yet the practical result is the same as that of former investigators of this cell—namely, that the cell is without value for the practice. Prof. R. Lorenz gave an interesting summary of the extended researches, made in his laboratory on the electrolysis of fused salts. The silver voltameter was the subject of a paper by Dr. K. E. Guthe, while Mr. A. G. Betts and Dr. E. F. Kern proposed the lead voltameter for commercial purposes—the latest outcome of the Betts lead refining process. Prof. H. S. Carhart and Dr. G. A. Hulett presented the latest results obtained in their investigation of the cadmium standard cell, with electrolytically prepared mercurous sulphate. The aluminium rectifier was the subject of two papers—one by Dr. Bancroft, the other (in section B) by Mr. Nodon. Dr. H. E. Patten's paper on the deposition of aluminium from ethyl-bromide solutions was specially interesting on account of the use of a non-oxygen containing electrolyte on the basis of the theory that the difficulty of getting an aluminium deposit is due to its immediate re-oxidation. Truly, this brief outline will show that Prof. H. S. Carhart was right, when, as the chairman of Section C, and as president the American Electrochemical Society, he congratulated the members on the character and variety of the papers presented.

THE PROPOSED INTERNATIONAL COMMISSION ON UNITS.

Before the International Electrical Congress met in St. Louis, the fear was expressed repeatedly in various European countries that hasty resolutions would be passed concerning units and standards. It was assumed to be due to such suspicions that England, France and Germany were slow to appoint official delegates. However, England and France, in the eleventh hour, gave official recognition to the Chamber of Delegates, while even Germany recognized it to a certain extent by appointing a single delegate, but without authority to vote on questions of units and standards. However, the proceedings at St. Louis will now convince everybody that all previous fears and suspicions were groundless. In the first place, it had never been the intention to bring the questions of units and standards before the general membership of the Congress; considerations of this kind were reserved to the "Upper House," the official Chamber of Delegates, appointed by the various countries. Moreover, the Chamber of Delegates eventually did not take any action whatever on any proposition brought before the Chamber with respect to changes in present standards or units or additions thereto. But the Chamber of Delegates did something which, we are sure, will turn out to be of far greater importance in future. In a resolution, printed on another page of this issue, it formulated a plan for the appointment of a standing international commission on units, to be named by the different governments, for consideration of all matters relating to electrical units, standards, notation, nomenclature and other matters concerning which it is desirable to have international uniformity.

It seems not too sanguine a view to hope that favorable action on this plan will be taken, since the delegates of the St. Louis Chamber will urge it on their governments. The result would be far-reaching. In the first place it would put an end to chambers of delegates sitting in connection with international congresses; undoubtedly this system had distinct disadvantages. Moreover, we may hope that the commission may eventually become a permanent one. Of course, much will depend on the gentlemen chosen for the commission. If the commission shall really further engineering and industries, it should consist rather of representatives of the profession, and not of bureaucrats. While electrochemical units are not specially mentioned, they would undoubtedly fall within the field of the commission. In this connection we may point out that the next International Congress for Applied Chemistry, to be held in Rome in 1906, intends to take up this question. It is surely in the interest of electrochemistry if the question is not taken up by a chemical or by an electrical congress, but by a commission of the kind which is planned.

SOCIETY OF CHEMICAL INDUSTRY.

A report of the general annual meeting held at Columbia University and an abstract of Sir William Ramsay's presidential address on the Training of Technical Chemists, will be found on another page of this issue. The rest of the programme for the days while the foreign guests stayed in New York City was carried out in accordance with the arrangements which had been most carefully planned. The result was correspondingly a huge success. Since the programme was published before in our columns we may simply mention that the roof garden reception at the Majestic Hotel was made impossible on account of the inclement weather, so that the reception had to be held indoors. The smoker and vaudeville entertainment at the Liederkranz Hall on Saturday night was a very enjoyable affair. Dr. H. Schweitzer presided over the smoker which was carried out in form of a German Kommers. A most numerous Kneipzeitung had been prepared. Sir William Ramsay presented an address of thanks signed by the European guests.

On Saturday afternoon, before the smoker, the members of the committee and several Europen guests were received by President Roosevelt at Oyster Bay.

Annual Banquet.

The banquet held on Thursday evening at the Waldorf-Astoria was most notable, on account of a series of excellent speeches. Dr. Charles F. Chandler, acted as toast-master, and was very happy and pertinent in introducing the various speakers. He first proposed the health of the President of the United States, which was drunk standing, and the health of his Majesty, King Edward, which was also drunk standing. Dr. Chandler, in announcing that the next toast would be the Society of Chemical Industry, called for a response from the retiring president of the society, and introduced Sir William Ramsay, with the remark that Sir William owed the society an apology for bringing into the chemical elements a lot of tramps, by his discovery of five of the laziest elements, like argon, about which nobody has ever heard a good word.

Sir William Ramsay, in responding to the toast said that by his presidential address he had hoped to bring in closer touch science and industry, and he expressed the hope that the new president, Dr. Nichols, would look at the other side of the sheet in his address next year and touch upon the relation of industry to science. He confessed to having been blamed for bringing into the world a set of lazy children—although there was a sort of step-father for one of them—and added that a new chemical child was born about two months ago, and that recent experiments had given him the hope that we may now find out the source of the ordinary chemical elements. It was a mere hope, however, so far. He expressed the hope that the union between the United States and Great Britain in the Society of Chemical Industry would last forever.

Dr. Chandler said that there is a society known in New York as Verein Deutscher Chemiker, which usually meets after the Society of Chemical Industry has met and brought forth and illustrated the latest developments of science; then tables are brought in, and the spigot is driven into a barrel and beer is circulated; then they say the Verein Deutscher Chemiker is in session. As an extraordinary envoy of this Verein he introduced Dr. H. Erdmann, of Charlottenburg, who, in his reply expressed the wish that in the chemical union between the United States and Great Britain, Germany might be the third party. A toast to the Verein Deutscher Chemiker was then drunk.

In proposing the next toast on industrial corporations, Dr. Chandler said the only person they could find with a corporation was Dr. H. W. Wiley, and this was probably due to his extended experiments with all kinds of poisons as food. Dr. Wiley, in responding, said that there is no danger of a dissolution of the union of the British and American members of the Society of Chemical Industry. He referred to a little fact in history; namely, that the United States parted from England because they were taxed without representation. But that is not so in the Society; "you tax us, it is true, but look at the representation which we have." So there is going to be no Boston Tea Party in the Society of Chemical Industry. There is a perfect community of interests. International meetings do more to draw together already strong ties than any amount of preaching in public prints can do. One sees one's fellow man face to face and begins to appreciate that after all it is the man as a man. In the great sphere of industry, it is the man who does things. We measure the man by the industry, but the man is the thing. Industry is incident to the man and his development, and it is because industries develop manhood and not because they bring dollars, that industries are useful to man.

Dr. Wilhelm Ostwald spoke of the international character of science. Science is the only thing which forms a part of the equipment of every human being which has reached some degree of civilization. He alluded to his latest favorite idea—that people in all countries might learn a universal language. He drank his glass to the furtherance of the idea of international brotherhood. "Science is brotherhood."

Dr. William H. Nichols, replying to the toast on American Chemical Industries, said that to pay the workingman well is an effective means of cheapening the cost of the product. In recalling names of pioneers in American chemical industries he referred to Mr. Weightman, of Philadelphia, who recently died, Mr. Martin Kalbfleisch and others, while the future of industrial chemistry in this country is in the hands of the young men. As a representative of the British Consul, Mr. K. Bailey spoke of his impressions of New York. As a representative of the English committee who arranged the trip, Mr. Thomas Tyrer spoke of the splendid hospitality of the New York Section and paid a glowing tribute to the ladies' committee. The last speech was made by Dr. Hugo Schweitzer, who was godfather when the New York Section was founded. He went into the history of the growth of this section. As chairman of the general committee of arrangements he expressed his thanks to Drs. Coblentz, Moore, Mr. Zabriskie and Drs. Parker and Love. The last two he called the "gold dust twins," they having looked after the financial end of the matter.

Tour Through the United States.

The tour through the country was carried out according to the programme, which has been printed before in these columns. The special train was provided with all possible comforts, bathrooms, barber shop, barroom, observation cars; even a stenographer and typewriter was present. In Philadelphia at the dinner at the Germantown Cricket Club, Dr. S. P. Sadtler, as chairman of the local committee, spoke some well-chosen words of welcome; Sir William Ramsay replied in his characteristic humorous mood and expressed the thanks of the guests for the splendid hospitality, while Mr. C. G. Cresswell gave an outline of the history and growth of the society. The reception of the society in Washington was equally splendid; the beauties of the city were greatly enjoyed, though inclement weather spoiled somewhat the trip to Mount Vernon.

The programme for Pittsburg was most extensive and well arranged, and the numerous visits to plants and works were extremely enjoyed. At the luncheon in the Union Club, Sir William Ramsay paid a well-earned tribute to the work of the local committee and its chairman, Mr. K. F. Stahl.

In St. Louis the programme had been so arranged that as much time as possible was at the disposal of the visitors to see the World's Fair and to attend the Congress of Science and Arts. But at the time when these notes were prepared for the press, no further details were available.

THE CHEMISTRY OF ELECTROPLATING.[1]

By Prof. Wilder D. Bancroft.

Although some results have been obtained by Mylius, Foerster, Glaser, Burgess and others, a glance at the recent text books on electrochemistry will show how far we still are from any consistent theory of electroplating. The reason for this is to be found in our neglect of the chemistry involved. The electric current is merely one agent for bringing about certain chemical reactions; but this is often overlooked, and many of us consider a decomposition by means of electricity as much more mysterious than a decomposition by heat, for instance. I hope to show that a study of chemical reactions and chemical analogies will at least give us the outlines of a theory of electroplating.

When we speak of a good metallic deposit, we may mean good from the point of view of the analyst, the refiner, or the plater. The analyst must have a deposit of pure metal in a weighable form, but that is all. The refiner must have a coherent deposit of pure metal, except in the case of silver. Neither the analyst nor the refiner cares about the smoothness of the deposit, so long as no trees are formed. The plater must have an adherent smooth deposit which will burnish to an apparently amorphous surface. In the preliminary discussion we will rule out the plater and will call a deposit good when it is pure and coherent. Afterward we can consider the further problem of the production of a very fine-grained deposit. Since there are very few data for anything except aqueous solutions, we will consider these only, though the general principles are equally applicable to all solvents.

When working with moderate current densities, a bad deposit is practically always due to the precipitation of a non-metallic solid with the metal. When one of the single salts in the bath is sparingly soluble, as with the cyanides, the salt may precipitate. In most cases, however, the trouble is due to the presence in the deposit of oxygen either as oxide, hydroxide or basic salt. Whatever will dissolve the salt readily under the conditions of the experiment will prevent its deposition, and should therefore improve the quality of the deposit. This has been recognized for zinc by Mylius and Fromm[2] and by Foerster and Guenther.[3] It has been put in a more general form by Glaser.[4]

I have made a list of the more important additions recommended in the refining, analysis, or plating of zinc, nickel, lead, tin, copper and silver. These are given in Table I.

Table I.

Zinc.	Tin.
Sulphuric acid.	Sulphuric acid.
Potash.	Potash.
Ammonium chloride.	Sodium pyrophosphate.
Ammonium sulphate.	Potassium carbonate.
Aluminium sulphate.	Acid potassium tartrate.
Potassium cyanide.	Potassium cyanide.
Acid potassium oxalate.	
Nickel.	**Copper.**
Sulphuric acid.	Sulphuric acid.
Ammonia.	Ammonia.
Ammonium salts.	Alkaline tartrate.
Potassium cyanide.	Ammonium oxalate.
Sodium bicarbonate.	Potassium cyanide.
Sodium bisulphite.	Sodium bisulphite.
Lead.	**Silver.**
Acetic acid.	Nitric acid.
Potash.	Ammonia.
Fluosilicic acid.	Potassium cyanide.
Sodium nitrate.	Potassium iodide.

All the substances under zinc dissolve zinc hydroxide. The first four under nickel dissolve nickel hydroxide; the sodium bicarbonate probably serves to keep the acidity constant; while the sodium bisulphite occurs only in solutions containing free ammonia. All the substances under lead dissolve lead hydroxide. Stannous and stannic acids are soluble in suphuric acid, in potash, and in a so-called sodium pyrophosphate solution; potassium carbonate is added only to neutralize an excess of free acid in stannous chloride solutions; while the cyanide and tartrate seem to be of very little value, unless, perhaps, at the anode. Under copper everything dissolves the hydroxide except sodium bisulphite and this is added to cyanide solutions to prevent loss of cyanogen when the copper changes from the cupric to the cuprous form. All four substances under silver dissolve freely-precipitated oxide; in addition ammonia dissolves silver chloride, while cyanide and silver iodide are soluble in potassium cyanide and potassium iodide respectively.

It is thus clear that there is a simple rational basis for many of the solutions in actual use. It must be kept in mind, however, that the rate of solution is more important than the actual solubility. Thus it is not easy to get a good solution from an alkaline zincate solution at 20° C., whereas it is a comparatively simple thing to do this at 40°, because the caustic soda reacts with zinc oxide or hydroxide much more rapidly at this temperature. It does not follow from this that a higher temperature would necessarily be even better. At 90° the action of caustic soda on metallic zinc becomes an important factor. With copper sulphate solutions rise of temperature means increased formation of cuprous sulphate, and this must be taken into account. In each of these cases a study of the chemical reactions shows the cause of the difficulty.

While there is much evidence in favor of Glaser's first generalization, that a metallic deposit is improved by adding to the solution substances which will dissolve the oxide, hydroxide or basic salt, there are only a few scattered experiments which can be cited in favor of Glaser's second generalization that reducing agents improve the quality of the deposit. Glaser[5] observed that addition of pyrogallol or hydroquinone to a lead bath improved the deposit of electrolytic lead. Engels[6] states that the addition of hydroxylamine makes it possible to use higher current densities in the analysis of copper. It is believed that tin salts in solution improve the quality of a copper deposit[7], and it is known that ferrous salts are not disadvantageous. Good deposits of many metals are obtained from cyanide solutions and part of the effect, though certainly not the whole of it, may be due to the fact that potassium cyanide is a reducing agent. It is also possible that the merits of a tartrate solution may be due in part to the formation of reducing agents by oxidation at the anode.[8] In some experiments made at Cornell we have found that hydrazine improves the electrodeposition of cobalt and that resorcin has a slight favorable effect with zinc, but apparently not with tin. The negative result in this last case may be due to the reducing power of the tin solutions. These instances will suffice to show that we do not yet know definitely how much influence a reducing agent has or how it varies with varying conditions. Since none of the reducing agents in question will reduce the oxide to metal, it seems very probable that the effect of the reducing agent may merely be to prevent oxidation by dissolved oxygen. If so, the effect should disappear in a vacuum or in an atmosphere of nitrogen. It has not yet been possible to try this experiment.

We have next to consider the effect of higher current densities. When solutions are not stirred we soon reach a point at which an ever-increasing density causes a bad deposit. This change in the quality of the deposit is always accompanied by

[1] A paper read at the International Electrical Congress in St. Louis. This is one of the three papers presented by special delegates of the American Electrochemical Society to the Congress.
[2] Zeit. f. Anorg. Chem., 9, 144 (1895).
[3] Zeit. f. Elektrochemie, 5, 16 (1898); 6, 301 (1899).
[4] Zeit. f. Elektrochemie, 7, 365, 381 (1900).
[5] Zeit. f. Elektrochemie, 7, 381 (1900). Cf., Elbs and Rixon. Ibid. 9, 267 (1903).
[6] Smith. "Electrochemical Analysis," 62.
[7] Borchers. "Elektrometallurgie," 193.
[8] Luther. Zeit. f. Elektrochemie, 8, 647 (1902); Schilow. Zeit. f. Phys. Chem., 42, 646 (1903).

an increased evolution of hydrogen, and it is usually believed that the evolution of the hydrogen is the cause of the deposit going bad. This cannot be the whole truth, because hydrogen is evolved freely during electrolytic analyses, and yet the deposit remains good. Further, the so-called critical current density varies enormously with the size, shape and distance apart of the electrodes, and also with the size and shape of the containing vessel, so that the data obtained by any one man usually cannot be duplicated by others. The most important factor is the rate of stirring. If we rotate a smooth copper, zinc or nickel cathode with sufficient speed, it is by no means certain that there is any current density at which the deposit goes bad. With tin there does seem to be a limiting density, but this is very possibly due to the formation of stannic salts in solution. It is intended to study this question in detail.

When a deposit becomes sandy or changes to a black powder, the polarization shows that there has always been the formation of a dilute solution at the cathode. In most cases this leads to the precipitation of an oxide or a basic salt with the usual disastrous results. It is still an open question whether this is always the case. Foerster and Seidel[9] say that sandy deposits of copper are not due to the presence of oxide. If this statement is correct, we shall be forced to the assumption that the badness of the deposit is due to the pulsating or intermittent precipitation of hydrogen as a result of the intermittent formation of a surface film impoverished as to metal. This explanation does not appeal to me personally and I prefer to believe for the present in the oxide formation, even if I have to account for the apparent absence of hydrogen by assuming a reduction to metal after the harm has been done.

Hydrogen may easily be indirectly the cause of a bad deposit. If hydrogen adheres as bubbles to the cathode, the deposition of the metal will become uneven and we shall have conditions favorable for treeing. A trouble of this sort can be cured chemically by adding an oxidizing agent to remove the hydrogen. It is known that copper solutions containing nitric acid will stand much higher current densities than will those acidified with sulphuric acid. It is clear that the prevention of hydrogen by means of an oxidizing agent may lead to the oxidation of the metal, in which case we are out of the frying-pan into the fire. Foerster and Guenther[10] had difficulties with hydrogen bubbles during the precipitation of zinc. They show that such oxidizing agents as chlorine and ammonium persulphate prevent the appearance of hydrogen without causing the formation of zinc oxide. Such oxidizing agents as hydrogen peroxide and ammonium nitrate prevent hydrogen evolution, but were worthless because they oxidized the zincs.

An oxidizing agent could probably be used to prevent occlusion of hydrogen by nickel, for instance. It is quite likely that the disadavantages would outweigh the advantages. In that case it would be better to approximate the same result by varying other conditions. The favorable conditions would be: a concentrated solution to ensure a good deposit; a high temperature to lower the absorption coefficient; a nearly neutral solution to increase the decomposition voltage of hydrogen; and a high current density to give a fine-grained metal. For any given rate of stirring we should expect a limiting current density beyond which deterioration would occur. With increasing current density we get a finer deposit, but there is also an increasing tendency to precipitate hydrogen, and it is necessary to strike a balance between these two. All these conditions have been found experimentally for nickel by D. H. Browne[11], with the one exception that he finds a large addition of sodium chloride advantageous. The reason for this is not clear.

Having considered the conditions for getting a good deposit from the refiner's point of view, we can now take up the question from the point of view of the plater. The problem is now as to the conditions under which the deposit is composed of very small, microscopic crystals.

When we precipitate a salt by chemical means we get larger crystals, the slower the precipitation and the higher the temperature. We should, therefore, expect that an electrolytic deposit will be coarser the lower the current density and the higher the temperature, provided all other conditions are held constant. The conclusion as to the current density is confirmed by all experiments. The case of the temperature change is a little more complicated, because we may have hydrolysis and increasing acidity or alkalinity; we may have increased solvent action, and we may have a displacement of equilibrium as with copper sulphate. The effects due to these changes will, of course, superimpose themselves on the pure temperature effect and mask or even reverse it. In some experiments, made in my laboratory, Mr. Enowdon found that the deposit from an acidified copper sulphate solution became coarser as the temperature was raised from 20° to 40° and to 70°. A similar result was obtained with a strongly acid zinc sulphate solution and with a lead bath. With nickel ammonium sulphate solution the effect of temperature on the crystalline structure of the deposit was too small to be detected. With a zinc sulphate solution which was only slightly acid, the deposit was more finely-grained at 40° than at 70°; but the deposit at 20° was coarser than either of the others. I suspect that at 20° the slight acidity had no appreciable effect on the deposit, while it became an important factor at 40°. This hypothesis is confirmed by the other experiment in which a more acid solution behaved normally.

For a given current density, temperature and salt solution, we should expect a coarser-grained deposit the more concentrated the solution. This has been found to be the case in experiments with zinc sulphate, and sodium zincate solutions. Since the potential difference between the metal and the solution is less the more concentrated the solution, it seems probable that this is an important factor when we change from one solution to another. Other conditions being the same we shall get the smallest crystals, the greater the potential difference between the metal and the solution. This is the recognized explanation for the excellent character of the deposits from cyanide solutions.

A natural corollary from this last is that the deposit will be more finely crystalline, the greater the solvent action of the solution. This accounts for the small crystals that are obtained from an acid copper sulphate solution or from one containing nitric acid. This conclusion, of course, holds only within the limits for which we get a good deposit. The converse of this would be that reducing agents should increase the size of the crystals. Mr. Snowdon has found that addition of formaldehyde to a copper or a zinc solution does make the deposited metal more coarsely crystalline. Resorcin has a similar effect with zinc. It will be difficult to get conclusive evidence on this point, because many reducing agents form complex salts and the effect due to this may easily overbalance the other. If the reducing agent acts only to remove dissolved gases, its effect on the size of the crystals would probably be negligible.

The addition of glue or similar substances to a solution tends to make precipitates come down in a colloidal form. Following out this analogy, we should expect to find that addition of glue or similar substances to an electrolyte bath would decrease the size of the metal crystals, the limiting concentration being that at which the added substance causes a bad deposit owing to its chemical properties. It is known that the success of the Betts process for refining lead is due in part to the action of glue in preventing trees. We have found that the addition of ten grams of glue per liter of acidified copper sulphate solution improves the quality of the deposit from the plater's point of view.

One final point is of importance to the plater, the adhesion of the deposit. It has been suggested that an adherent plating deposit can be obtained only when the two metals can com-

[9] Zeit. f. Anorg. Chem., 14, 125 (1897).
[10] Zeit. f. Elektrochemie, 5, 22 (1898).
[11] Electrochemical Industry, 1, 348 (1903).

bine to form compounds of solid solutions.[12] This has also been denied.[13] While I have not made any experiments myself, I feel certain that Burgess is right and that this is purely a question of chemistry. The surface between two metals is a thin weld, and it must show the same strength no matter how it has been made. In other words the adhesion of an ideally-made electrolytic deposit will approach that of a casting having the same size of crystals. Presence of grease, of air-bubbles, or of occluded mother liquor will impair the contact and weaken the joint. If the metal is deposited in a state of strain, the break will come at the weakest point. These are matters of general knowledge in making welds or castings, and they are just as much first principles in electrolytic work. No one seems to have been struck by the absurdity of the statement to be found in most books on plating that nickel cannot be plated on nickel because it will not adhere. If this were true it would not be possible to deposit more than in infinitesimally thin film of nickel electrolytically. While it requires a higher voltage to deposit nickel than copper, nickel does not precipitate copper to any appreciable extent when immersed in a copper sulphate solution. The nickel becomes passive and is probably covered with a thin film of oxide. What people mean is that an "active" nickel containing hydrogen will not adhere to a "passive" nickel. There is nothing surprising or mysterious about this.

The alleged rusting of iron, when plated with nickel in a chloride instead of a sulphate solution, if really true, is purely a chemical phenomenon and rests on the different behavior of occluded chloride and sulphate solutions. If the distinction is a real one, special experiments would soon show whether the freedom from rust in sulphate solutions is due to the iron becoming passive or to the formation of an insoluble basic salt.

The general results of this paper are:

1. A bad deposit is always due to the precipitation with the metal of some salt or non-metal.

2. Addition to the solution of anything which will dissolve this salt or non-metal will tend to prevent its precipitation and to improve the quality of the deposit.

3. Any beneficial action of a reducing agent is probably due to the removal from the solution of dissolved oxygen.

4. A fine-grained deposit is favored by high current density and potential difference, by acidity and alkalinity, by low temperature and by colloids.

5. Solutions containing oxidizing agents appear to yield small crystals, while larger crystals are obtained from solutions containing reducing agents.

6. The adherence of deposits rests on the adhesion of the two metals.

The discussion has been incomplete. The formation of the "trees" has only been touched upon and the question of "bright" deposits has not been raised. All of the generalizations rest on insufficient evidence. On the other hand, the consideration of the chemistry of electroplating has given us a working hypothesis which can be tested experimentally.

[12] Kahlenberg, Electrochemical Industry, 1, 201 (1903).
[13] Burgess, Electrochemical Industry, 1, 204 (1903).

ELECTROMETALLURGY OF IRON AND STEEL IN CANADA.

We have repeatedly referred in our columns to the great interest which is being taken in Canada in the use of the electric furnace in the iron and steel industries. Concerning the trip of a committee, appointed by the Canadian Government, to study various processes of this kind in Europe, we published notices on pages 48, 198, 280 and 329 of our present volume.

We are now informed that an electric furnace plant on a very large scale is to be erected at Ottawa, Canada, for the reduction of pig iron from iron ores in connection with the electric production and refining of steel. Thus, the electric furnace will enter into competition with the blast furnace.

DIFFERENCES IN THE ELECTROLYSIS OF POTASSIUM CHLORIDE AND SODIUM CHLORIDE.

By F. Winteler, Ph. D.

At first glance it might appear that there should be no differences between the phenomena during electrolysis of potassium chloride and sodium chloride, with the exception that on account of the higher atomic weight of potassium the same current yields in the same time more potassium hydroxide than sodium hydroxide (theoretically 2.095 grams of caustic potash, 1.496 grams caustic soda and 1.323 grams of chlorine per ampere-hour). There are, however, other differences.

In the first place, commercial common salt is never pure, while pure potassium chloride may be had in trade. Common salt contains in the average 1 per cent of magnesium chloride and 1 per cent of sulphuric acid which is bound as sulphate. For most of the other chemical purposes for which common salt is used, these impurities are unimportant, while they are of the greatest importance for the electrolytic process of making caustic soda and chlorine, as well as chlorate The content of magnesia is advantageous for chlorate manufacture, since it raises the efficiency of the process; on the other hand, it makes the use of a diaphragm cell unsuitable for the manufacture of caustic soda. The content of sulphate has the same effect.

Secondly, common salt has about the same solubility at ordinary and at higher temperatures, while potassium chloride is much more soluble at higher temperatures than at ordinary temperatures. This fact causes differences in the evaporation of the cell solutions, whereby potassium chloride must be separated from caustic potash and sodium chloride from caustic soda. The designs of the apparatus are different for the electrolysis of the two salts.

Thirdly, potassium chlorate (which is formed in the anodic compartment during the cathodic production of KOH solution in a diaphragm cell) is only slightly soluble in water at ordinary temperatures; and even at elevated temperatures its solubility in concentrated potassium chloride solution (of which the anolyte consists) is rather small. On the other hand, sodium chlorate is easily soluble in water and in concentrated sodium chloride solution. If concentrated sodium chlorate solution is added to a concentrated sodium chloride solution, the latter is precipitated, but no chlorate.

This high solubility renders the use of a diaphragm cell unsuitable for the electrolysis of sodium chloride, since chlorate would gradually accumulate in the anodic compartment; it would then take part in the electrolysis resulting in the development of oxygen and of chlorine containing carbonic acid.

On the other hand, the high solubility of sodium chlorate at elevated temperatures is utilized for separating it from common salt, which has about the same solubility at ordinary and at higher temperatures. If a concentrated solution of the mixture is cooled, pure sodium chlorate is precipitated, chloride remains in solution.

The facts briefly outlined above, may now be discussed more in detail.

Electrolytic Production of Caustic Potash.

The question whether the use of a diaphragm cell is suitable for the electrolytic production of caustic potash must certainly be answered in the affirmative.

Commercial potassium chloride is 98.5 per cent pure. The balance of 1.5 per cent is made up nearly exclusively of moisture and of some ferric oxide. The latter remains back in the solution tank or in the filter press. The filtered solution represents pure potassium chloride. The first products during electrolysis are pure chlorine at the anode and potassium hydroxide at the cathode. Then the latter begins to participate in the electrolysis and OH ions travel into the anodic compartment, forming some chlorate. Since the KCl solution is maintained concentrated in the anodic compart-

ment, the chlorate which is being formed, is at once precipitated. It falls to the bottom of the anodic compartment and cannot have any deleterious effect.

If the KCl solution would not be maintained highly concentrated in the anodic compartment, chlorate would dissolve in larger quantities; it would then participate in the electrolysis and would cause destruction of the carbon anodes as well as the liberation of greater amounts of oxygen and carbonic acid in the anodic chlorine than are found in concentrated solutions.

Electrolytic Production of Caustic Potash.

The question whether the use of a diaphragm cell is suitable for the electrolytic production of caustic soda should, in my opinion, be answered in the negative, for the following three reasons.

First, the content of magnesia in commercial common salt causes the diaphragm to be clogged. At the boundary surface of the cathodic sodium hydroxide solution and the anodic sodium chloride solution saturated with chloride—*i. e.*, in the diaphragm—magnesia is deposited. Under analogous conditions, the sodium chloride electrolysis requires, therefore, in practice, 7 volts, while 3.6 volts are sufficient for the electrolysis of potassium chloride.

Secondly, the content of sulphate in the sodium chloride solution continually increases in the anodic compartment for the reason that SO_4 ions migrate into the same from the cathodic compartment, while new quantities of sulphate are continually added by filling new sodium chloride (containing sulphate as impurity) into the cell. The consequence is that the chloride electrolysis changes gradually into a sulphate electrolysis, resulting in the destruction of the carbon anodes as well as of the diaphragm.

Thirdly, as soon as caustic soda is formed in the cathode compartment by electrolysis, hydroxyl ions migrate into the anode compartment, which, on account of the excess of chlorine present therein, results in the formation of chlorate. Since sodium chlorate is easily soluble, it remains in solution, and participates in the electrolysis. The result is that the carbon anodes are destroyed and that the chlorine contains oxygen and carbonic acid.

Differences in the Evaporation of Caustic Soda and Caustic Potash Solutions.

While the mercury cathode process and the Acker process yield at once pure caustic alkali solutions, the other electrolytic methods (diaphragm process and gravity [Glocken] process) require a separation of undecomposed chloride from the caustic alkali. As is well known, the ampere-hour efficiency would be too low if one would try to change all the chloride into hydroxide. If a mixture of caustic soda and sodium chloride is evaporated until the specific gravity is 50° Baume, all sodium chloride (except 1 per cent) is precipitated even at high temperature.

The case of potassium chloride is quite different. If a mixture of potassium chloride and potassium hydroxide is evaporated until the specific gravity is 50° Baume (one should not go further, since at 52° Baume the solution solidifies when cooled), several per cent of potassium chloride remain still dissolved at the high temperature. It is therefore not possible (as in the case with caustic soda) to provide the evaporation apparatus with a device for separating the potassium chloride from the caustic potash. In this case the mixture of precipitated potassium chloride with potassium chloride dissolved in caustic potash is passed into tanks where it is allowed to cool; this is followed by separating the precipitated crystals from the solution which now contains only 1 per cent of potassium chloride, either by filtration under pressure or vacuum or by centrifugal force.

Differences in the Electrolytic Production of Potassium Chlorate and Sodium Chlorate.

If potassium chlorate is produced by electrolysis of potassium chloride, the conditions of operation may be so chosen that it precipitates in the cell itself on account of its small solubility, or it precipitates when cooled in another tank into which the hot solution is passed. The potassium chlorate thus obtained contains small amounts of potassium chloride, and by simple recrystallization in hot water, the commercial product is obtained.

Since sodium chlorate is consideraby more soluble in sodium chloride solution, it is preferable to apply in this case another method. Even in this case it is possible to get sodium chlorate crystals on the bottom of the electrolyzing cell, if the content of chlorate is pushed beyond 850 grams per liter, with 10 per cent sodium chloride. But the ampere-hour efficiency is greatly reduced under such conditions of operation, and it is, therefore, preferable, when working on an industrial scale, to push the content of $NaClO_3$ not beyond 500 or 600 grams per liter, with 10 to 12 per cent NaCl. This solution is brought into the vacuum evaporation apparatus where it is concentrated until the specific gravity is 52° Baume. Under these conditions the main part of sodium chloride is precipitated; the solution is then passed through a hot filter and cooled. Sodium chlorate then precipitates nearly free from chloride, and it may be easily purified by washing with water.

While the content of potassium chlorate in the cell solution is insignificant, the content of sodium chlorate in the cell solution is ten times as great.

The content of magnesium in common salt becomes here again of importance. During electrolysis the cathode is covered with a crust of magnesium hydroxide, and this results (as first described by Oettel) in an increase of the ampere-hour efficiency. The reason is that less hypochlorite is reduced. This exists in the cell as an intermediate product generated in the change from chloride to chlorate.

Finally, I may call attention to the fact that additions to the solution, intended to increase the efficiency, have not the same effect in electrolyzing potassium chloride and sodium chloride. It is well known that an addition of bichromate increases the efficiency of the production of chlorate. But in practice this addition is suitable only for potassium chlorate manufacture.

In the latter case fresh salt is again and again dissolved in the old mothor liquor, and the addition of bichromate is made only once, and does not need to be renewed. It is different with sodium chlorate manufacture, where, after evaporation the mother liquors are not returned into the cells, but pass only through the short way from the evaporation apparatus to the crystallization vessels. The cells are supplied with fresh salt to which fresh bichromate would have to be added again. After completion of electrolysis and evaporation, these quantities of chromate are contained in the old mother liquors so that chromate accumulates in the same until a point is reached when the sodium chlorate crystals are no longer white, but yellow.

If bichromate is to be used in the manufacture of sodium chlorate, the chromate should be precipitated from time to time by means of barium chloride. It is, however, preferable not to use this addition at all, since the presence of sulphate from the original water of solution may lead to difficulties in connection with the filtration of the precipitates.

It will thus be seen that there are essential differences in the electrolysis on an industrial scale of potassium chloride and sodium chloride.

"Sixty-Mesh Screen."—In a recent issue of the *Engineering and Mining Journal* attention is called to the confusion existing in the literature concerning the use of the form "mesh." It is remarked that some journals use the term "3600-mesh," where universal usage in this country would apply the term 60-mesh. A 60-mesh screen contains 60 holes per linear inch, or 3600 holes per square inch. There should be absolute uniformity in the use of technical terms.

ELECTROLYSIS AND CATALYSIS*.

By Prof. W. Ostwald.

The chemical result of the conduction of an electric current through an electrolyte is made up of two very different effects, namely, the phenomena of the conduction through the electrolyte and those concerned with the *transfer of electric charges* at the electrodes. With respect to the first effect, we have clear and definite conceptions based on the universally confirmed theory of Hittorf. According to this theory, the mechanism is of the greatest simplicity, namely, the cations and anions migrate in opposite directions and with mobilities which depend mainly on the specific nature of the ions, but also on the solvent, the concentration and the temperature. The process which results in the second effect, namely, the ionic discharge or the general transfer of charges at the electrodes, also seemed at first to be simple and clear. True, the assumption that the ions which accomplish the transportation of the current through the electrolyte are also the materials which undergo the electric change at the electrodes, could not be supported; it was the recognition of the fact that both can be different, which enabled the development of the proper explanation of the phenomenon of electrolytic conduction itself. Berzelius still based his electrochemical system on such an incorrect conception of the electrolytic phenomena. He at first and chiefly tested the salts of the alkaline metals and earths; since *bases* and *acids*, besides hydrogen and oxygen, result from their electrolysis, he regarded the former two substances as the real constituents of the salts, and based his entire chemical system on this misconception derived from his experiments. Even Faraday held rather erroneous views in this regard, though we owe to him the name and conception of the ions. The first one who was consistent was Daniell, who throughout assumed the metals to be the cations of the salts. This scientist's conception of the mechanism of the transportation of electricity by the ions was still imperfect, and it was then Hittorf who worked out the theory in this respect to perfect simplicity and clearness; to him we owe the statement that electrolytes are salts, and the experimental methods for determining the nature of the ions in every given case, as also the relation of their migration velocities independently of any possible electrode reactions.

The new idea of decisive importance was that of a *secondary reaction*. While by the conduction of the current through the electrolyte a certain ion may be transferred to the cathode, it does not necessarily follow that it is there deposited or liberated. In a solution of potassium chloride it is undoubtedly the potassium ion which transports the positive electricity to the cathode. Yet it does not appear there as the product of electrolysis, but in its stead, potassium hydroxide and hydrogen are formed. This is explained by the conception that directly or primarily potassium is deposited, which, however, cannot exist in contact with the water of the solution and reacts with it, forming potassium hydroxide and hydrogen.

First of all, this view enables us to conceive the same simple mechanism for the conduction of the current through an electrolyte, in the two theoretically fully analogous cases of the electrolysis of the salts of heavy metals which do not decompose water, and the electrolysis of the salts of light metals which decompose water, although both cases are apparently quite different from an experimental point of view. Another result is that the apparent contradiction to Faraday's law is avoided, which in the case of electrolysis of salts of light metals, could be found in the fact that, besides liberation of oxygen and hydrogen, the formation of acid and alkali appear as immediate effects of the electrolysis. Finally our view gives an explanation of the fact that in some cases, instead of the secondary reactions, it is possible to get the primary products by means of a slight modification of the conditions of the experiment. For instance, in the case of the alkali metals this is possible by the use of a mercury cathode.

In the course of time, the necessity has manifested itself to consider a great many reactions as secondary. The best-known example is the decomposition of water between inert electrodes. Since water itself is a poor conductor, alkali or acid is added and in former descriptions of this method it was stated that these additions are made only for the purpose to render the water a "better conductor." Now we know with sufficient certainty that the conduction of the current is really accomplished by the ions of the additions, and, in the case of an acid, we consider the oxygen developed at the anode as the result of a secondary reaction between the discharged anion and the solvent water, while in the case of an alkali, we must assume secondary reactions even at both electrons, namely, at the cathode the reaction between alkali metal and water, and at the anode the change of the discharged hydroxyl ion into oxygen and water.

By the development of modern electrochemistry our views on these questions have been modified so as to be more precise. If at an electrode, several processes are possible by means of which the transfer of electricity from the electrolyte into the electrode may take place, we have to assume that that reaction will take place for which the potential difference is a maximum. Or, in other words, if we gradually increase the e. m. f. applied at the terminals of the cell, beginning with zero e. m. f., then, of all possible ionic discharges, those will first occur which require the smallest potential difference.

However, the potential difference for any electrode reaction has in general not a constant value, but depends upon the temperature and to a considerable degree upon the *concentration;* and the latter manifests its strongest influence exclusively at *low* concentrations. If we start from "molar" solutions and increase the concentration, we cannot go beyond ten-times molar concentrations for experimental reasons, because more concentrated solutions of electrolytes cannot be prepared in general. Within the limits mentioned, the maximum possible difference is about 0.06 volt for the electrolytic production of any constituent of these solutions, out of the concentrated or out of the dilute solution. On the other hand, if we start again with molar solutions and decrease the concentration, the same difference of e. m. f. (0.6 volt) is found for every decrease of the concentration to one-tenth its former value; hence, for 0.001 molar solution, compared with molar ones, it is already 0.17 as maximum, and for 0.000001 molar solutions it is twice as much. For infinitely dilute solution it is theoretically infinite; but experimentally one does not come beyond 2 volts.

The following important conclusion may herefrom be drawn. If there are several possibilities for the reaction at one electrode, the really occurring chemical reaction depends not only on the nature of the possible chemical reactions, but upon the concentration of the substances which are present, and by suitably varying the latter, we can bring any reaction to any point in the voltage series.

Now, it is a universal fact that the electrolytic process itself results in a decrease of the concentration of that substance in the neighborhood of the anode which is involved at that moment in the electrode reaction. Hence, any such reaction has the tendency to stop by itself and to be replaced by that reaction which can and will take place as the next one with increasing voltage. Moreover, since the voltage is influenced only by the concentration *at the electrode itself*, not by the average concentration in the whole electrolyte, this "polarization" would necessarily take place almost instantaneously after the current has begun to flow, if there were not other processes which bring the exhausted kind of ion again in sufficient quantity to the electrode.

These compensating influences are of a two-fold kind. First we have diffusion which tends to make good any decrease of concentration with a force proportional to the existing con-

* A paper presented at the International Electrical Congress.

centration difference. Secondly, we may have chemical reactions which are caused by the exhaustion of the electrolytically changed ions, since the quilibrium which had been disturbed by their disappearance begins to restitute itself, and therefore also tends to counteract the loss. Both compensating processes start, however, only after the loss had been established, and are therefore never able to reproduce the original condition. The result is always a polarization, *i. e.*, an e. m. f. which counteracts the applied e. m. f.[1]

The value of the e. m. f. of polarization depends evidently upon the final decrease of concentration of the electrolytically changed ion. For this purpose we have to consider the stationary condition which is reached after the first variable processes have terminated. For the case that the compensation for the exhausted ions is accomplished by diffusion only, Helmholtz has already given the principles of what takes place. This may be briefly summarized as follows:

The current causes a consumption of the active ion at the electrode surface, the quantity consumed being proportional to the quantity of electricity which has passed. But the electrolytic migration of the ions does not bring as many new ions to the cathode as are consumed, but only a certain portion of this number, this portion being given by the ratio of the migration velocity of the active ion to the sum of the migration velocities of both ions. Hence, there must necessarily result ionic exhaustion which is counteracted by diffusion. The exhaustion progresses so far until diffusion—which has simultaneously increases on account of the increasing concentration difference—brings exactly the missing amount of ions in form of its salt to the electrode. There will be produced, therefore, finally, a certain distinct concentration difference between the electrode surface and the main part of the solution, and there will be a corresponding distinct e. m. f. of polarization. Since the diffusing quantity of salt is proportional to the coefficient of diffusion and to the *difference* of concentration, while the e. m. f. of polarization is proportional to the *ratio* of the concentrations, it follows that with the same current density the e. m. f. of polarization must become the greater, the smaller the total concentration of the active ion.

These considerations hold good directly for primary electrolysis in which the current is transported by the same ion which undergoes the change of concentration at the electrode. For secondary electrolysis we have only to consider what the influence o fthe current will be, according to Faraday's law, upon the concentration of the electrolytic ion at the electrode. Let us consider, for instance, the case of "water decomposition," and let us distinguish the two cases in which, for increasing the conductivity, an acid or a base is added. With an acid solution we have to consider at the cathode the concentration of the hydrogen ion and we have primary electrolysis At the anode we had to consider first the concentration of the anion, for instance, the SO_4 ion. By its reaction with water, oxygen and sulphuric acid is formed according to the equation,

$$SO_4 + H_2O = H_2SO_4 + O$$

i. e., this process yields sulphuric acid which disintegrates again into its ions. The concentrations of the SO_4 ion is therefore not diminished, but increased, and this increase corresponds exactly to the decrease of the concentration at the cathode. Diffusion will now carry the sulphuric acid from the anode away, and this will lead to a stationary condition. The total result is not a compensation of the two e. m. f's. of polarization at the electrodes, but since an *increase* of concentration has a smaller influence on the potential than an equal *decrease*, in the whole we will have a polarization in the ordinary sense, *i. e.*, the passage of the current is rendered more difficult and this will be the case to a greater extent the higher the current density and the smaller the total concentration.

[1] There are known a few cases of abnormal polarization in which the current causes an e. m. f. of polarization of the same direction as the applied e. m. f.; their theoretical explanation is possible on the basis of theory given in the following:

If a caustic potash solution is electrolyzed, we have a similar increase of the potassium hydroxide concentration at the cathode, due to the ionic migration, since it is not removed there from the solution, and we thus have here quite similar conditions as exist for sulphuric acid near the anode. At the anode we have in the case of caustic potash electrolysis, the reaction, $2OH = H_2O + O$. The concentration of the HO is approximately equal to that of the potassium, but the latter decreases on account of the migration of the ions. Further, immediately at the anode a layer of pure water is formed. The total result in this case is again a polarization in the ordinary sense.

All these considerations are based, however, upon the further supposition that *the chemical reactions by which the secondary products are formed, occur with a speed infinitely great in comparison with the other processes.* This is a supposition which, while very approximately fulfilled in the cases which we have considered, yet is not necessarily fulfilled in all cases. If we have to do with reaction velocities which are not infinitely great, there arise a great many new questions which we did not need to answer so far.

It may be asked, for instance, whether at the anode in a potassium hydroxide solution the secondary reaction $2OH = H_2O + O$, or even $4OH = 2H_2O + O_2$ occurs, or whether we have rather a primary reaction, namely, the discharge of bivalent oxygen ions. True, the existence of such an ion O'' has not yet been proven; it can never exist in considerable quantities, because it reacts soon with water according to the equation,

$$O'' + H_2O = 2OH'$$

and forms hydroxyl ions. On the other hand, one may state that it must always be present in very small quantities wherever hydroyl ions are present, since the above reaction also takes place in the reverse direction, as read from the right to the left hand of the equation, and the simultaneous concentrations of the two kinds of ions are determined by the (unknown) equilibrium constant of this reversible reaction. As long as this reaction also takes place with a speed which is infinitely large compared with that of the electrolytic processes, it does not matter which reaction is assumed, since no measurable quantity is thereby influenced; it is therefore not possible to decide which of the different possible reactions really occurs, and a discussion on this point does not fulfill any useful purpose.

Let us now imagine the possibility of rendering the reaction between hydroxyl ions and bivalent oxygen ions infinitely slow by some means. It would then be possible to decide which of the two reactions occurs at the electrode (under the supposition that it is either the one or the other). If it is the hydroxyl ion which is discharged, the decrease of concentration, produced by a given current, will have a relatively much smaller effect than an equivalent decrease of concentration of the oxygen ion which is present in a much smaller concentration. Under equal conditions we would, therefore, get a small polarization in the first case, and a very strong polarization in the second case; and by measurements of the polarization we could decide which of the two reactions really takes place.

Such means of changing the speed of a given reaction within very wide limits, exist really in chemistry in what is called *catalyzers.* Herefrom it is at once evident which very esential and important part the catalyzers are able to play in electrolytic action. By retarding one of the possible reactions by means of a negative or retarding catalyzer, we are able to *exclude* its influence from the electrolytic process. By accelerating by means of a catalyzer a reaction which is of itself slow, we can *include* it into the electrolytic process. In other words, we are no longer compelled to let the current act in the way stated by the above simple law, but in principle, we are now able, *by applying suitable catalyzers, to prescribe to the current that reaction which we want to take place*, and it does

not matter at which point of the voltage series this reaction is situated.

This fundamental idea may be applied in two directions. First, in *synthetic* work; if we suppress by negative catalyzers those reactions which would take place before the desired one, we can bring the desired reaction to the front, or, if the reactions which take place before the desired one, occur with a low speed, we can accelerate the speed of the desired reaction by means of a positive catalyzer, and can thus produce the same effect. The second application is *for analyzing the reactions which really take place at the electrodes.* If these reactions are essentially influenced by a certain addition, and if we know the single reaction which is altered catalytically by the addition, we can conclude that this reaction takes an essential part in the electrode process. If a catalyzer of known specific activity does not influence the electrode reactions, we can draw the reverse conclusion and state that that reaction is not a part of the electrode process.

In connection with this, it should be emphasized that what is called above briefly *"the electrode process,"* is in reality a rather complex phenomenon. In the simplest case—for instance, in the primary electrolysis of a silver salt—this reaction consists in the change of the silver ion to metallic silver. But "metallic silver" is not a well-defined substance, since we know elementary silver in very different allotropic states. Here the very general rule manifests itself that a system, when changing from one state to another one, first assumes the unstable intermediate states which change step by step into more stable ones; in the case of explosive antimony, detected by Gore, it is well known that one of these states remains metastable for a longer time. One may say, therefore, that the first product in the cathodic deposition of silver is that which is formed as the next step from the silver ion after the loss of its positive charge—*i. e.*, silver dissolved in water, probably of the molecular weight Ag. On account of the presence of white metallic silver the silver cannot continue to exist in this state, but changes into the stable form of white silver. At the cathode a distinct proportion of dissolved silver ions to dissolved silver metal will therefore be established, and this proportion will determine the potential by means of an equation similar to that given by Peters[2] for the potential of a mixture of ferrous and ferric salts. The greater the speed of the charge of dissolved silver into the white solid metal, the smaller will be the concentration of the dissolved silver metal and the more it will approximate that which is given by the self-solubility of white silver[3], and which therefore represents the equilibrium potential of a silver electrode.

Similar considerations hold good for the secondary reactions at an electrode. Thus, as primary anodic product of the electrolysis of dilute sulphuric acid a substance SO_4 may be assumed which reacts with the solvent water with any (probably very high) speed, to form oxygen and sulphuric acid. In the case of concentrated sulphuric acid which contains mainly the ion HSO_4', not the substance HSO_4, but its polymerisation product, $H_2S_2O_8$ is obtained, or its ions, as conceivable primary product. If, however, the anode has too strong catalytic properties, for instance, if it consists of a large platinum plate, the persulphuric acid which is formed soon disintegrates into sulphuric acid and oxygen, and the unstable intermediate product does not remain.

It will thus be seen that even the simplest electrode reactions are made up of a plurality of reactions following each other step by step. Since each of the same can be influenced catalytically, it is already evident that a very great variety of results is possible. We should further consider that many of the unstable substances, which, during electrolysis are formed as intermediate products and which quickly disappear, are not yet known separately with respect to their properties, and especially with respect to the action of catalyzers upon the same. Under these circumstances it will be evident what an abundance of peculiar and unexpected phenomena we may hope to detect in this way, and how much new knowledge we may expect to obtain from a systematic investigation of this field. The literature of electrochemistry already contains a great number of separate facts which are not only understood more easily, but applied with greater safety, if considered from the points of view given in this paper. I regret I cannot go into details; I only wish to remark that for some time Prof. LUTHER, with his scholars, has attacked this problem from different sides; the papers already published by them, and even more the still unpublished investigations, will show the generalty and variety with which this scientist has understood to develop this principle and to render it useful.

[2] Zeit. f. Phys. Chemie, v. 26, p. 200, 1898.

[3] Such a solubility must be assumed in any case. This follows from general reasons and from the facts, detected by Naegeli, of the storing poison action, the "oligodynamics" of water in contact with metallic silver.

THE MANUFACTURE OF FERRO-ALLOYS IN THE ELECTRIC FURNACE.

By GEORGE P. SCHOLL, PH. D.

(*Continued from page* 351.)

A third process of manufacturing the alloy consists in using an impure carbon containing a high percentage of silica for the manufacture of calcium carbide and adding iron to the charge. The alloy is thus obtained at the same time as the carbide. Jouve (loc. cit.) maintains that such procedure gives very impure products on account of the formation of alkaline earth silicides which remain in the carbide as well as in the alloy. The alkaline earth silicides are stated to retain with great facility the impurities, such as phosphorous, sulphur, arsenic, which exists in the carbons used and especially in the impure material, which is always rich in pyrites. Alloys manufactured by this process were exhibited at the Paris exposition in 1900. It may suffice here to briefly mention a method proposed by Gin, which is described in ELECTROCHEMICAL INDUSTRY, Vol. 2, page 149, and which consists essentially in the formation of an alkaline or alkaline earth silicate in one electric furnace and the reduction of the silicate in a second electric furnace after it has been mixed with the requisite quantities of oxide of iron or metallic iron and carbon. Alkaline or alkaline earth oxides are thus obtained in connection with the ferro-alloy. He states that in order to obtain ferro-silicon with about 20 per cent of silicon, the mixture is made up according to the formula $BaSiO_3 + Fe_2O_3 + 5\ C = Fe_2Si + BaO + 5\ CO$, or with metallic iron $BaSiO_3 + 2\ Fe + 2\ C = Fe_2Si + BaO + 2\ CO$. The operation is stated to be carried out with a current of between 25 and 35 volts, the expenditure of energy being between 50 and 60 watts per square centimeter section of the electrode. The barium silicate has previously been obtained by treating a mixture of barium sulphate, broken quartz or non-clayey sand and charcoal in another electric furnace.

The method proposed by Tone, described and illustrated in ELECTROCHEMICAL INDUSTRY, Vol. 2, page 111, though primarily intended for the production of metallic silicon, may also be mentioned here.

Albert Keller, in his paper before the Iron and Steel Institute mentioned above, gives some particulars as to the manufacture of ferro-silicon according to his process at Livet, France. He states that its manufacture can only be carried out with real economy in a large installation and with powerful electric furnaces. Those in use at Livet are of 650 hp. each, and they are of the resistance type, presumably similar to the one described above. The raw materials employed are preferably quartz, scrap iron and coke. Quartz is more suitable than sand, inasmuch as the latter often occasions obstructions in the furnace. Scrap iron and steel are preferred to iron ore, for the reason that, working with a pure quartz, the work proceeds without the formation of any appreciable amount of slag. The purity of the product obtained is almost exclusively dependent upon the care taken in manufacturing.

Keller states that the energy acquired to manufacture 1 ton of ferro-silicon containing 30 per cent of silicon, amounts to 3500 kw.-hours. A works disposing of 10,000 effective horse-power on the turbine shaft could, therefore, produce 16,000 tons of ferro-silicon annually, or about 50 tons per day. Power of 4000 hp. is devoted in Livet to the manufacture of ferro-silicon. Analysis of the 50 per cent alloy manufactured by Keller, are given as containing phosphorus 0.02 per cent, sulphur a trace and carbon a trace.

Some data relative to the manufacture of ferro-silicon by the Willson Aluminium Company, at Kanawha Falls, W. Va., are given by Dr. Haber in the *Zeitscrift f. Electrochemie*, Vol. 9, page 363, in the course of a report on the electrochemical industries in this country. He states that the manufacture of the alloy is carried out with iron ore, river sand and coke, the two latter being obtained quite cheaply. A cheap supply of scrap iron is not available. The composition of the iron ore is Fe 62.34 per cent, SiO_2 7.93 per cent, P 0.4 per cent, MgO 0.09 per cent, CaO 0.72 per cent and S a trace. An average sample of the product showed the following composition: Si 28.11, Fe 69,02, Cr 2.27, S 0.04 Mn trace, P trace, C 0.54. The chromium content is accidental, being due to the manufacture of ferro-chromium in the same furnace. The expenditure of energy for the production of one kilogram of silicon in the product is given as 26½ hp. hours, which is equivalent to $26.5 \times 300 = 7950$ hp. hours for the 30 per cent alloy per ton, or 5930 kw. hours.

Gin, in a paper in L'Eclairage Electrique, Vol. 27, May 4, 1900, details a number of experiments undertaken by him on the manufacture of ferro-silicon. He worked with hammer scale, quartz and coke, with siliceous iron ores, quartzy sand and coke, and with slag from the acid Martin furnace and coke. When using hammer scale, quartz and coke, he obtained 200 grams per kw. hour, of an alloy of the following composition: Si 21.45, Fe 77.50, undetermined 1.05. This is equivalent to an energy expenditure of 5000 kw per ton of alloy. For this he calculates the cost per ton as follows: electric energy, 31 francs (a rate of about 50 francs per kw. year of 365 days); labor, 15 francs; hammer scale, 36 francs; quartz, 9 francs; coke, 29 francs; electrodes, 24 francs; maintenance and repairs, 13 francs; amortisation, 20 francs; divers general costs, 23 francs, making a total of 200 francs (about $40) for the 20 per cent material. Undoubtedly the cost is less now than that amount.

When working with siliceous iron ores of the composition Fe_2O_3 59.2 per cent, MnO 2.1 per cent, SiO_2 24.6 per cent, water of combination and moisture 14.7 per cent, undetermined 9.4 per cent, a sand of 93.7 per cent, SiO_2, undetermined 2.1 per cent, moisture 4.2 per cent and a coke of 78.9 per cent of carbon, 11.3 per cent of ash and 9.8 per cent of moisture, in the following proportion: iron ore, 1800 kilograms; quartz sand, 420 kilograms and coke, 720 kilograms, he obtained a consumption of energy of 6200 kw. hours per ton of a product containing about 47 per cent of Si, the yield for the latter being 80 per cent.

Trials with acid Martin slag, which contained 50.42 per cent of Si_2, 2.26 per cent Al_2O_3, 34.10 per cent FeO, 9.92 per cent MnO, and 3.30 per cent of CaO, MgO, etc., with a mixture of 1680 kilos of slag and 600 kilos of coke, with 80 per cent of carbon, resulted in an expenditure of 5380 kw. per ton of a product containing Si 29.64, Fe 53.70, Mn 13.18, carbon 0.52, undetermined 2.96. The average current was 6950 amperes at 29.1 volts.

The difference in the amount of energy required per ton of ferro-silicon is easily explained when it is borne in mind that the expenditure of energy increases with the amount of silicon contained in the product obtained. The great discrepancies in the figure given by Keller, namely, 3500 kw. hours, and for Wilson, viz., 5930 kw. hours for an alloy of approximately the same silicon contents, is brought about by the former's employment of metallic iron, while the latter uses iron ore. A simple thermochemical calculation of the heat units required for the reduction of the silicon in the two cases will show that the efficiency of the furnace is not much different in the two cases.

The following calculation will give an approximate idea of the difference in heat units required for the production of one ton of 30 per cent ferro-silicon, when manufactured from metallic iron, silica and carbon, and from iron ore, silica and carbon. The following values are assumed: 1 kg. Fe for reduction from Fe_2O_3, requires 1796 cal., 1 kg. Si from SiO_2 requires 7830 cal., 1 kg. C burning to CO develops 2473 cal., spec. heat of Fe from 0° to 1400° C. average = .20, spec. heat of SiO_2 = .25, spec. heat of carbon = .50. It is assumed, for simplicity's sake, that the reduction takes place exclusively according to the formula $SiO_2 + 2C = Si + 2CO$, and that the materials used are chemically pure. It is, of course, not difficult to make a similar calculation for the impure materials as they are actually used in practice. Under the conditions assumed the theoretical heat units required for a ton of 30 per cent alloy will be as follows:

Heating up 700 kgs. Fe to 1400° C. = $700 \times .20 \times 1400 =$ 196,000 cal. Heating up 643 kgs. Si to 1400° C. = $643 \times .25 \times 1400 = 225{,}050$ cal. Heating up 257 kgs. C to 1400° C. = $257 \times .50 \times 1400 = 179{,}900$ cal. For reduction of 300 kgs. Si from SiO_2 $300 \times 7830 = 2{,}349{,}900$ cal. A total of 2,950,850 cal. Heat gained by burning of 257 kgs. C to CO = $257 \times 2473 = 635{,}561$ cal. Total heat required = 2,315,289 cal., which is about 2730 kw.-hours. Comparing this with the figure of 3500 kw.-hours, mentioned above as given by Keller as actually obtained in practice, and taking into consideration the unavoidable losses of heat in practice and the heat required for various purposes owing to the impure materials dealt with, which have not been considered in the above calculation, it is apparent, that the efficiency of his furnace is quite satisfactory.

When the calculation is made for the production of an alloy of the same percentage from oxide of iron, silica and carbon, assuming also in this case the materials to be chemically pure, the heat requirements are as follows:

Heating up of 1000 kgs. Fe_2O_3 to 1400° C. = $1000 \times .19 \times 1400 = 266{,}000$ cal. Heating up of 643 kgs. SiO_2 to 1400° C. = $643 \times .25 \times 1400 = 225{,}050$ cal. Heating up of $225 + 257 = 582$ kgs. C to 1400° C. = $582 \times .50 \times 1400 = 407{,}400$ cal. Reducing 700 kgs. Fe from $Fe_2O_3 = 700 \times 1796 = 1{,}257{,}200$ cal. Reducing 300 kgs. Si from $SiO_2 = 300 \times 7830 = 2{,}349{,}900$ cal. Total, 4,505,550 cal. Heat gained by burning of 582 kgs. C to CO = $582 \times 2473 = 1{,}439{,}286$ cal. Total heat required = 3,066,264 cal. This amounts to about 3565 kw.-hours. The figure actually obtained by Wilson, as given by Dr. Haber (l. c.), in the manufacture of a 25 to 30 per cent alloy, is 5930 kw.-hours. Considering the greater metallurgical complexity of the ore process as compared with the smelting of iron borings, and the additional heat requirements for driving out moisture, and for various reactions, no account of which has been taken in the above calculation, this figure is also quite satisfactory for practical purposes.

(To be concluded.)

AMERICAN ELECTROCHEMICAL SOCIETY.

At the meeting of the Board of Directors, held on Sept. 2, the following gentlemen were elected members of the Society: F. E. Schmitt, New York City; James G. Marshall, Niagara Falls, N. Y.; Timothy C. Root, Buffalo, N. Y.

At the October meeting the names of the following gentlemen will come up for election: Elliott M. Sergeant, Boonton, N. J.; E. P. Schock, Austin, Texas; Martin L. Griffin, Mechanicsville, N. Y.; E. S. Wittnebel, New York City; F. E. Schuetz, New York City.

The spring meeting, 1905, of the Society will be held in Boston, invitations having been extended by representatives of Harvard University, and of the Massachusetts Institute.

ELECTROCHEMISTRY AT THE INTERNATIONAL ELECTRICAL CONGRESS OF ST. LOUIS.

The fifth International Congress met at St. Louis on the morning of September 12 in the Music Hall of the Colesium. While the acceptances of membership were over 2000, the number of members who attended the Congress personally was about 715.

The inaugural general meeting was called to order by Prof. Elihu Thomson, who introduced Hon. D. R. Francis, president of the World's Fair, who welcomed the Congress to St. Louis. He expressed the opinion that it would be a long time, in this country at least, before another universal exposition would be attempted, but that there will probably be international expositions in special lines, and he believes that electricity is the one field in which there is likely to be another international exposition before a great many more years. He paid a tribute to the excellence of the electrical part of the St. Louis Fair, which is under the direction of Prof. W. E. Goldsborough.

Prof. Elihu Thomson, in his address outlined the organization of the Congress and complimented the general secretary Dr. A. E. Kennelly, and the treasurer, Mr. W. D. Weaver, on the excellent and very effective work they had done. The Congress then proceeded to effect its regular organization and speeches were held by foreign delegates. After the conclusion of the general meeting the Congress then revolved itself into its constituents' eight sections, as follows:

Section A.—General Theory—Mathematical, Experimental. Chairman, Prof. E. L. Nichols; Secretary, Prof. H. T. Barnes.

Section B.—General Applications. Chairman, Prof. C. P. Steinmetz; Secretary, Prof. Samuel Sheldon.

Section C.—Electrochemistry. Chairman, Prof. H. S. Carhart; Secretary, Mr. Carl Hering.

Section D.—Electric Power Transmission. Chairman, Mr. Charles F. Scott; Secretary, Dr. Louis Bell.

Section E.—Electric Light and Distribution. Chairman, J. W. Lieb, Jr.; Secretary, Mr. Gano S. Dunn.

Section F.—Electric Transportation. Chairman, Dr. Louis Duncan; Secretary, Mr. A. H. Armstrong.

Section G.—Electric Communication. Chairman, Mr. F. W. Jones; Secretary, Mr. B. Gherardi.

Section H.—Electrotherapeutics. Chairman, Dr. W. J. Morton; Secretary, Mr. W. J. Jenks.

In the following we give a full report of Section C (Electrochemistry). The programme of this section had been arranged with the effective co-operation of the American Electrochemical Society and the two meetings on Tuesday and Thursday were joint meetings of Section C and of the Electrochemical Society, while on Friday an independent meeting of the American Electrochemical Society was held which had no official connection with the Congress. In the following report, however, the meetings of Section C and of the American Electrochemical Society are reported together.

Report of Meeting of Section C (Electrochemistry) and of the American Electrochemical Society.

Monday Session.

Immediately after the inaugural general meeting of the Congress had been closed, section C, devoted to electrochemistry, assembled, with Prof. Hy. S. Carhart as chairman and Mr. Carl Hering as secretary. On account of the limited time at disposal, only one paper was presented at the Monday session.

The Relation of the Hypothesis of Compressible Atoms to Electrochemistry.

A paper on this subject was presented by Prof. Theodore William Richards, of Harvard University. In the absence of the author it was read by Prof. G. W. Patterson. The idea had occurred to the author that since affinity binds chemical elements firmly together in compounds, it should also exert pressure, and should therefore tend to combat all the influences existent in matter tending to distend the substance. The mutual affinity of two elements in a compound should, therefore, tend to diminish the volume of this compound; and, other things being equal, the greater the affinity, the greater would be the change of volume and the smaller would be the final volume of the resulting compound. If this relation really held true, it should be most clearly perceptible in compressible substances; hence, a number of compounds of the easily compressible halogens, chlorine, bromine and iodine, were studied with regard to this possible relationship. It was discovered that, in general, the volume of a solid chloride or bromide was much less than the sum of the volumes of the metal and the liquid chlorine or bromine entering into its composition; and, moreover, the more energetic the reaction, the greater was the change in volume during its progress. That is to say, a great affinity evidently causes a great contraction.

The relation, although in some cases quite striking, is in other cases concealed by other circumstances, especially by the differences in compressibility of various substances. It has recently been shown that, as one would expect, the more compressible the element, the greater the contraction which occurs for a given expenditure of energy. The demonstration of this additional fact is a strong evidence that affinity really exerts pressure, and that the volume of a liquid or solid is dependent upon the intensity of this pressure. The attraction of cohesion also was shown to exert a similar effect. When corrected for the compressibility of the factors in a reaction, and for the cohesion of both factors and products, the correspondence between the output of chemical energy and the change of volume during the reaction becomes so close as to leave little doubt as to the fundamental nature of the relation. In any attempt to penetrate further into the reason of these facts, some assumption avowedly hypothetical, must be made concerning the ultimate nature of material. For the present purpose the atomic hypothesis furnishes the most convenient foundation.

The further question now presents itself: What is that which is compressed by this pressure? In other words, what is the distending tendency in solids or liquids? Does the pressure of affinity simply restrict the vibrations of separate hard particles in an empty space, or is the atom itself compressible? The author thinks that the former usually accepted hypothesis does not sufficiently explain the difference between a solid and a gas.

The purpose of the paper of Prof. Richards is to show that the hypothesis of compressible atoms, dealing, as it does, with very intimate relations of energy and material, is not without suggestiveness to the electrochemist, and hence also to the electrical engineer.

In the first place, one may ask: How would a compressible atom behave on leaving an electrode and going into solution as an ion? It would then be attacked by an entirely new set of affinities, being in its new position surrounded by molecules of the solvent, instead of by atoms similar to itself, and these new affinities exerting new intensity of pressure would be expected to change its volume. Moreover, the solvent, being itself in part exposed to new internal pressures, would also change in volume. As a matter of fact, a marked change of volume is always observed when a positive and negative element go into solution in the ionized conditon. The author quotes the examples of potassic chloride, sodium chloride and potassic bromide. Among these similar compounds, and in many other cases, it usually appears that the greater the

electrical potential afforded by the double ionizaton, the greater the change of volume; also, the greater the compressibility of the elements concerned, the greater the change in volume. These changes of volume on ionization also seem to be approximately parallel with the changes of volume on forming the corresponding hydroxides; just as the heats of ionization are approximately parallel with the heats of formation of the hydroxides. This parallelism may indicate that the effective agency causing ionization or galvanic solution of a metal is the attraction of the metal for the oxygen or the hydrogen of water—most probably the oxygen. Although these regularities are fairly prominent on comparing the properties of similar elements in a natural group, exceptions are not hard to find on comparing very dissimilar substances. At least, a part of these exceptions may be traced to the expected simultaneous contraction of the solvent. That the solvent really often contracts is manifest from the fact that in some cases (notably the hydroxides of lithium, sodium, and barium, and the sulphates of zinc, cobalt, nickel and magnesium) the solution occupies less space than the water alone, from which it is made. In this connection the author calls attention to the well-known fact that during the formation of eighteen grams of water from its ions in the neutralization of a strong acid by a strong base, an increase of volume of 20 milliliters occurs—an increase greater than the volume of the water formed.

Another less direct relation of the theory of compressible atoms to electrochemistry is to be found in the effect of change of volume of reacting systems upon their specific heat. Thomsen pointed out long ago that a contraction in a reaction between aqueous solutions is usually accompanied by a loss of heat-capacity of the reacting system; and it is possible to cite many other cases in which is is true. Probably, however, the cause of this loss is not so much the decrease in volume, as the irregular stress caused by tthe simultaneous presence of very different affinities. In terms of the hypothesis of compressible atoms—atomic distortion seems to cause a diminution of heat capacity. As a kinetic conception. this interpretation is plausible.

The relation of this change of heat capacity to electrochemistry is very important. Recent study has made it appear highly probable that a change in heat capacity during a reaction is the chief, if not the only, reason why the total-energy change (or the heat of reaction) is not equal to the electrical work which the reaction performs in a galvanic cell. In colloquial language, the heat energy which is displaced, or forced out, by a diminution of heat-capacity, does not seem to be able to perform work. If this be true, change of heat capacity is responsible for the "bound energy" of a galvanic cell, and, therefore, according to Helmholtz's equation, for its change of potential with the temperature. If, further, the preceding conclusion based upon the theory of compressible atoms be also accepted, the fundamental cause of this temperature coefficient of the electromotive force is referred back to atomic compression and distortion, which diminish the possibility of heat-vibration in the compressible atom.

The author then gives an explanation of Faraday's law on the basis of the theory of compressible atoms. To the electrochemist who has nothing to do with electrical capacity, the quantity-dimension of electricity is important merely as a number. He recognizes it only because it is proportional to equivalent weight of deposited metal, or to equivalent volume of evolved gas. Still more simply, it may be said to represent to him nothing but the number of atomic contacts which are made or broken in a given reaction. Therefore, the electrochemist, attempting to discover the relation of the compressible atom to galvanic deposition, naturally first seeks to imagine what would happen to a compressible atom on making or breaking a firmly united atomic contact with another atom.

Evidently, for each union with other atoms, a given atom would give and suffer a shock of impact or combination. The exact effect of this shock upon the atom itself cannot be determined; but if the atom is compressible throughout, many forms of vibration or temporary rhythmical distortion might be possible because of this shock. One of the most probable forms is, perhaps, a vortex motion; and it will be seen that this form lends itself best to further interpretation. If the atom were perfectly elastic, such a vortex would continue to exist indefinitely, when once formed.

We may imagine, then, that each collision of atomic combination starts or transfers a vortex or some other form of self-perpetuating shock. Then the deposition of a given number of chemical equivalents will result in the transfer of a given number of shocks, or a given quantity of electricity, and Faraday's law is explained. In short, in order to conceive logically of this law, one need not ascribe weight or mass to the electron—a permanent vortex will represent the needed unit as well as a ponderable particle. But only a compressible atom could hold or carry such an infinitesimal vortex, hence this hypothesis is dependent upon the hypothesis of compressible atoms.

This easy explanation of Faraday's law without a material conception of electricity leads one to inquire whether or not other relations of electricity might not likewise be satisfied by a vortical conception of the unit of electrical quantity. A complete study of the details of this possible explanation would be out of place, but a few of the electrical properties of substance may be mentioned in this connection. For example, the electrical conductivity of solids is in many cases what it would be expected to be, if their atoms were compressible. Atomic distortion would be expected to interfere with the ready transference of the vortices. The simpler the crystalline form, the less distorted would be the individual atoms, and the more easily would the vortices be received and transmitted from one atom to another. On the other hand, with irregular atoms, permanently distorted by chemical affinity, the uneven structure would receive and transmit the vortices less easily, and the potential energy of the mutual repulsion would be converted into heat. As a matter of fact, the two best electrical conductors among metals, silver and copper, crystallize in the regular system, and the poorest solid conductors among pure metals, bismuth, antimony and arsenic, are of less symmetrical crystalline structure. The non-metals which are all poor conductors, are still more noticeably complex in symmetry.

The relatively slight conductivity of alloys and compounds points in the same direction; for heterogeneity of atomic structure would imply irregular internal pressures, great atomic distortion, and hence, poor conductivity. The considerable effect on conductivity of even slight impurity in a metal and the extremely low conductivity of substances like glass and cellulose are well known, and accord with this interpretation.

Again, it is easy to see how increased thermal energy, which, if atoms are compressible, must be supposed to exist as a simpler oscillation of a portion of the atomic centers, would interfere with the reception and transmission of this new vortex-motion, and hence to see why the conductivity of solids should decrease on raising the temperature. Moreover, one would expect the slightly distorted atoms, easily receiving the electrical vortex, should usually likewise transmit more rapidly the simpler oscillations of heat energy, which is a fact.

The explanation of the brilliant experiments of J. J. Thomson and his pupils on the basis of the vortical electron is possible, if one admits, as Thomson is quite willing to do, the existence of electrical inertia independent of gravitational effect. In this case, the cathode ray is to be considered as a collection of disembodied vortices, which may only be driven through the wave-bearing medium under the stress of great difference of potential. Another alternative must be adopted if one doubts the somewhat complicated evidence concerning the relative masses of the cathode-corpuscle and the atom,

and believes the two to be identical. In this case it is necessary to imagine that a single atom can receive many vortices under the peculiar circumstances attending the cathode discharge; *i. e.*, that it is polyatomic.

The author does not claim that the hypothesis of compressible atoms represents truly the actual fact; indeed, atoms, in any shape, are an imaginary conception which may not have any counterpart in reality. "It has been claimed by a few that any hypothesis is harmful, but some of the most brilliant of scientific workers have used them as a continual inspiration. Faraday, one of the greatest of pioneers, dreamed thousands of such scientific day-dreams. To him, these were nothing but a benefit; for, although led on by visions, he knew well the difference between substance and shadow. He never confounded hypothesis with fact; and when new facts overthrew a favorite imagination, he would discard the latter gladly, rejoicing that it had led him to the discovery of the new truth."

The discussion of the paper was very brief. Prof. H. S. Carhart made a remark with respect to Richards' application of his hypothesis to the Gibbs-Helmholtz equation; he thinks that this hypothesis would only explain those cases of galvanic cells in which the temperature coefficient of e. m. f. is negative; *i. e.*, when heat is given off to the outside during an isothermic discharge. Prof. Patterson remarked that the other case would also be explained, if actual expansion would be observed.

Tuesday Session.

The session on Tuesday was a joint meeting of Section C of the International Electrical Congress and of the American Electrochemical Society.

Electrical Extraction of Nitrogen from the Air.

A paper on this subject was presented by Mr. J. Sigfrid Edstrom. The author points out that the demand for Chile saltpeter is increasing and the consumption growing heavier every year in spite of the rapidly rising prices. It is chiefly used for manufacturing nitric acid and fertilizers. In the year 1901 the consumption of Chile saltpeter in Germany

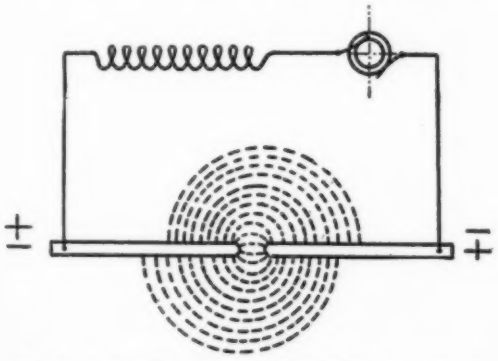


FIG. 1.—FIXATION OF ATMOSPHERIC NITROGEN.

alone was 500,000 tons. Of this quantity 75 per cent were used for fertilizers, 20 per cent for the manufacture of nitric acid, 3 per cent for the manufacture of nitrate of potash, and 2 per cent for the manufacture of sulphuric acid. The saltpeter mines in Chile are not inexhaustible; on the basis of statistical data the author estimates that they will be exhausted somewhere about 1940.

Under these circumstances it is not to be wondered that in several ways other means of producing compounds of nitrogen have been sought. The nitrogen which is contained in the air has been the source which has most naturally been turned to in seeking to produce a commercially useful article. The Siemens & Halske Co., of Berlin, investigated a method invented by Dr. Frank for manufacturing cyanamide of calcium ($CaCN_2$). Originally carbide of calcium was heated and treated by a current of nitrogen. The nitrogen was obtained by carrying a current of air over glowing copper. The copper unites with the oxygen of the air and the nitrogen remains. Later, the same results were obtained by carrying the nitrogen over a heated mixture of chalk and carbon in the same proportion as used in making calcium-carbide. The cyanamide of calcium has been tried as a fertilizer with good results. The method of Frank is as yet, however, only in its experimental state.

Most of the experiments for the manufacture of compounds of nitrogen are, however, based on a compound with oxygen. The author gives a review of the work of Priestley and Cavendish, Bradley and Lovejoy, de Kowalski and Moscicki, and describes then at length the process of C. Birkeland and S. Eyde, of Christiana. Prof. Birkeland and Mr. Eyde based their arrangements on the well-known fact that the electric current in the arc and with it the arc itself, can be deflected by a magnetic field, the deflection being at right angle to the lines of force.

If the horizontal electrodes are connected to a generator in series with a suitable inductance coil, and a strong magnetic field is applied near the electrodes in horizontal direction and at a right angle to the direction of the electrodes, the arc between the electrodes will momentarily be carried upward or downward. It will then be broken, while simultaneously a new straight arc is formed between the electrodes, which is again carried outwards, etc. The speed of the formation, motion and breaking of the arcs is so rapid that the arc can

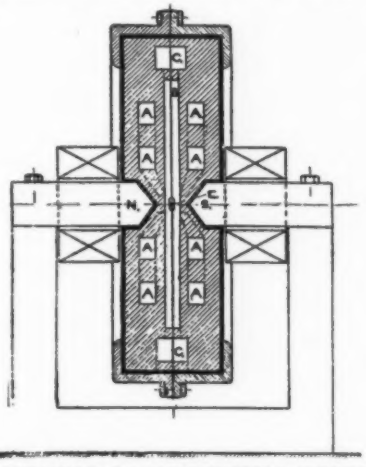


FIG. 2.—FIXATION OF ATMOSPHERIC NITROGEN.

be formed several thousand times a second. In the practical form of the ovens only some hundred arcs per second are used.

If the magnetic field is excited by a direct current, and the generator delivers direct current for the arc, a continual series of arcs will be formed, moving radially with a speed corresponding to the strength of the magnetic field. The striking points of the arc along the surface of the electrodes are also moving away from the points at the same speed. Thus the phenomena appear to the eye like a disc of arcs with the shape of almost a complete semi-circle. The movement of the arc near the electrodes is usually more rapid at the negative than at the positive electrodes, shifting the center of the circular disc somewhat to one side of a line joining the electrodes. If the magnetic field is excited by alternating current, and the arc is fed by direct current, the arcs will vibrate between opposite sides of the electrodes. This will also be the case if the arc is fed by alternating current and the magnetic field by direct current, in which case the phenomena will appear as indicated in Fig. 1. It is principally this arrangement which has been used by the inventors.

Fig. 2 shows the electric oven complete in a vertical section at right angles to the electrodes. The air that is to pass the oven is forced through the channels *A* and from there into the arc-chambers of the oven *B*, around and in the neighborhood of the electrodes *E*. Having passed this space from the center, and coming into the most intimate contact with the disc of arcs, the air passes out into the channel *C*, and leaves the oven mixed with a certain percentage of oxidized nitrogen.

The chief differences between this apparatus and that of former inventors are pointed out as follows by the author. While, with Bradley and Lovejoy and de Kowalski's methods, the energy in every arc must be lowered to the least possible in order to obtain an economical system, the method of Birkeland offers no objection to employing large amounts of energy in the disc of arcs. On the other hand, experiments have proved that the economical efficiency increases with the amount of energy employed at the electrodes.

One of the ovens, which is still in operation, has consumed from 75 to 200 kilowatts in the disc of arcs between one single pair of electrodes, and lately an oven with a disc of arcs for 500 kilowatts has been built. The 200-kw. oven has been fed with alternating current of 50 cycles frequency and 5000 volts pressure.

In spite of the relatively large current, the electrodes in Birkeland's oven have up to the present been used without interruption for several hundred hours. Owing to the fact that the striking points of the arc move along the electrodes, the destructive influence of the arc is inconsiderable. The electrodes can, for this reason, be made of very cheap material, such as copper or iron, and of such dimensions that they can easily be cooled by means of air or water, keeping their temperature within reasonable limits.

In the oven of Birkeland and Eyde, which was built about a year and a half ago, a small amount of energy was used in the disc of arcs, only seven to ten kilowatts. The efficiency of this apparatus was at first only 400 kilograms HNO_3 per kilowatt and year. The next ovens were constructed for an increased consumption of energy and have now, through continual improvements reached an efficiency of 900 kilograms HNO_3 per kilowatt and year. The energy referred to is the amount of energy in the disc of arcs itself. Some of the factors that have been considered in connection with the improvement of the oven are: The degree of moisture in the impressed air, its temperature, its amount of oxygen, the amount of air impressed per kw.-hour, the different strengths of electric current used, the voltage of the electric current, the frequency, the ovens arranged in series and parallel electrically, as well as with regard to the impressed gases, the strength of the magnetic field, the insulation of the oven to prevent the loss of heat, the introduction of various contact substances.

The air coming from the oven contains about 2 or 3 per cent of nitric oxide (NO). In order to be utilized it must be transformed into nitrogen peroxide (NO_2). This is done in a reaction tank of thin sheet iron enamelled on its inner side. From the reaction tank the gases go through an exhauster of clay, where they come into contact with drips of thin nitric acid. From here the gases pass on through the absorption system, consisting of four towers for water and one tower for a solution of caustic soda. In each tower the fluid is sent through the tower several times. The strongest acid runs always through tower No. 1, where the gases first pass, the next strongest through tower No. 2, and the weakest through tower No. 4. When the desired concentration is reached in tower No. 1 the acid is removed. The acid from tower No. 2 is then put into No. 1, from tower No. 3 into No. 2, and No. 4 into No. 3. Through tower No. 4 new water is passed. The process thus works according to the counter-current principle. The alakli tower contains, as previously noted, a solution of caustic soda. The gases from No. 4 pass through this tower. The remainder of the gases is absorbed here, and a mixture of nitrate and nitrite of soda is formed. From this pure nitrite of soda is manufactured. The acid taken from tower No. 1 is either concentrated by use of Valentiner apparatus and shipped, or is turned into nitrate of calcium or nitrate of potassium. The process is said to have been put into actual operation, compounds of nitrogen being manufactured.

In the discussion which followed Prof. C. F. Burgess pointed out that the figure of the output given by the author, namely, 900 kg. HNO_3 per kw.-year, indicates a pretty high efficiency, if HNO_3 means 100 per cent acid. Mr. Edstrom confirmed this, but called attention to the fact that 900 kg. is the output per kw.-year, the electrical energy being that consumed in the arc itself; the total power consumption is therefore greater. Moreover, power is not by any means the only item of expense. Dr. E. F. Roeber remarked that if the arc is fed with direct current and for the magnetic field which deviates the arc, a revolving field is used (such as applied in the primary of an induction motor), the arcs will cover a globe rather than a disc, and would, therefore, act on a greater quantity of air; it might thus be possible to get a still higher efficiency. Mr. Edstrom replied that he did not know that experiments in this direction had been made.

The Chemistry of Electroplating.

A paper on this subject was then presented by Prof. Wilder D. Bancroft, of Cornell University. It is printed in full on another page of this issue. The paper elicited an animated and interesting discussion, which was opened by Dr. E. F. Kern, who read a long communication by Mr. A. G. Betts.

Mr. Betts believes that some of Prof. Bancroft's generalizations are based on insufficient or untrustworthy experimental evidence. He states especially that he has repeated all experiments in the articles of Glaser on lead deposition, and has been entirely unable to verify this author's results; he therefore concludes that no theories should be based on them. He also objects to Prof. Bancroft's statement that a fine-grained deposit is favored by high-current density, and says he found that it is favored rather by a low-current density.

Mr. Betts considers that there are two main causes for the failure of an electric deposit. Either it may fail from being slimy, grading off into being soft, unsound and weak. He believes that this is due to the co-deposition of foreign conducting particles, in general caused by the presence in the solution of a small quantity of some metal of less chemical affinity than the metal being deposited. The foreign metal is precipitated in the minutest particles all over the surface, and if it comes down in too large quantity, or its affinity for the main metal is so weak that it is not immediately absorbed into an alloy, the same phenomenon takes place on an atomic scale which takes place, on a visual scale, when, for example, copper is being deposited and particles of slime are floating in the electrolyte. A particle of anode slime attaches itself to the cathode and very soon causes the formation of an insecurely attached lump of solid metal. The lumps are usually very easily knocked off, and a particle of slime is almost invariably found underneath. A slimy metal must consist of such lumps on an infinitesimal scale.

The other cause of failure considered by Mr. Betts is the growth of a deposit toward the anode; the more elevated a particular point is from the cathode surface, the more rapid its growth. There are then formed differences of concentration, in fact we can here apply the theory of concentration cells.

In depositing antimony from a solution of antimony trichloride, in which ferric chloride was continually introduced in small quantities, Betts obtained a deposit that was as smooth and shiny as glass. In this case the ferric chloride in the solution performed the function of continually cutting off projections as fast as started. By the time the iron salt had reached an incipient cavity, it had passed and already

reacted with the antimony of a neighboring projection, so that the rate of reaction was less, the less the particular point was in the current of solution. The amount of ferric chloride used was from 1-10 to 1-5 the amount necessary to redissolve all the antimony deposited.

In depositing silver from a nitrate solution, the deposit consists of more or less loose crystals, and projections are formed. From a cyanide solution the deposit is clean and solid. Mr. Betts thinks the reason is that with the cyanide solution the e. m. f. of the minute concentration cells that must exist at the cathode is much smaller than with the nitrate solution.

In the dissolution of an anode the conditions are exactly reverse to those at the cathode. A solution which will give projections at the cathode, ought for the same reason to give pits in the anode. In the dissolution of a lead anode in a fluosilicate solution, Mr. Betts has noticed that with gelatine present, the surface of the lead underneath the anode slime remains much smoother than in the absence of gelatine. This fact would seem to prove that the cause of projections at a cathode is not to be sought in the chemical composition of the deposit, but in the physics of the solution.

The next speaker was Dr. Louis Kahlenberg, who emphasized that the chemical make-up of a solution is the vital factor; compared with this, current density, potential, temperature, etc., are only of secondary importance. He thinks that Bancroft has made an excellent beginning, and every electroplater should give this matter his careful attention. Concerning the formation of an alloy at the boundary surface of cathode and deposit, he said that from Roberts-Austen's experiments it is sure that there is really a diffusion of one metal into the other, an alloying.

Dr. E. F. Kern said that to get a smooth deposit, it is necessary that no impurities should be introduced mechanically into the deposit. He referred to his and Betts' experiments with the lead voltameter (see the paper below).

Prof. C. F. Burgess said that electroplating, while the oldest electrochemical industry, is still in bad shape. One often does not get the same results as former experimenters; this is often due to the fact that the descriptions of experiments do not give all details. Concerning Betts' statement that the particles of impurity appear to attract the current, he thinks there is rather a treeing around the same. He thinks that everybody who has worked in this field will remember instances which, in one point or another, appear to contradict some of Bancroft's generalizations.

Prof. Bancroft, in his reply, wished such discrepancies would be pointed out to him, so that they could be tested. He showed that some criticisms of his paper were based on misunderstandings. He concluded that the object of his paper is to state concisely some general principles which can be tested experimentally, and which thus can be shown conclusively to be either right or wrong.

The Carbon Cell.

A paper on this subject, by Prof. F. Haber and Dr. L. Bruner, of the Institute of Technology, of Carlsruhe, Germany, was then read, in the absence of the authors, by Prof. Burgess. The object of the paper is to give an explanation of the action of the Jacques cell, which consists of carbon, fused sodium hydrate, iron; and the explanation offered by the authors is that it acts as an oxygen-hydrogen gas cell.

The iron electrode in the fused sodium hydrate is gradually covered with a protecting layer or skin of oxide. As soon as this has been produced, the iron is no longer attacked, while previously it went into solution in the fused salt as iron oxide, with the development of hydrogen gas. This protecting skin can be produced rapidly if the iron is dipped for a short time into fused saltpeter, and subsequently, carefully freed from the saltpeter by means of water. The iron thus coated with this protecting skin, is called "passive," because the fused sodium hydrate produces no further changes on it.

This passive iron represents an oxygen electrode on which the atmosphere oxygen acts similarly, but better, than on a platinized platinum electrode dipped into an aqueous conducting solution. This action of the oxygen is brought about by the presence of sodium manganate, which is always present in small quantities in fused commercial sodium hydrate, and especially when in contact with commercial iron, and its presence can easily be proved chemically.

The passive iron, as an unattackable electrode, can be replaced by another inert electrode, for instance by platinum, and without changing the force and the method of action of the electrode in fused sodium hydrate containing manganese.

If platinum is placed into pure sodium hydrate the potential at the electrode is uncertain. A very small quantity of a manganate suffices to give rise to a different value, which does not change during a further addition of a manganate up to 2 per cent of the weight of the sodium hydrate.

If the added sodium manganate is reduced by forcing in some hydrogen or carbon monoxide, or by the addition of sodium oxalate or sodium formate, quite an extraordinary change will take place in the potential. But by forcing in some atmospheric oxygen the original value of the potential is again reached.

"In these experiments the potential of the platinum electrode is thus brought about by the absorption of oxygen. If a permanganate is added to fused sodium hydrate, oxygen will be evolved and the potential will, contrary to the other case, be brought about by the evolution of oxygen. These potentials are measured most simply by letting the syphon of a decinormal-electrode terminate in a small vessel containing concentrated sodium hydrate, which is in electric contact with the fused salt which is to be tested, by means of a rod of solid sodium hydrate. In all the measurements the fused salt was in a large silver crucible. The observed values are collected in the following table for different temperatures. The temperature was measured thermoelectrically.

Centigrade degrees, 312, 336, 360, 388, 412, 472, 532.
Potential in volts against decinormal-electrode, —0.265, —0.294, —0.314, —0.333, —0.353, —0.431, —0.472.

These values were measured with a platinum electrode, a small quantity of the manganate being added to the sodium hydrate. Numerous tests showed that absolutely equal values of the potential are obtained with an electrode of passive iron."

On the other hand, when a carbon electrode is tested in the way above described for iron and platinum, all possible values can be observed between —0.6 and —1.5 volts toward the decinormal-electrode. With closer study one finds that the potential approaches the value —1.5 volts more and more, the more rapidly the carbon is attacked in the fused sodium hydrate with the evolution of gas. Ordinary arc light carbons can generally be made to produce a free gas evolution when the fused salt in which it is dipped is heated to above 500° C. They then reach quite or nearly the value —1.5 volts and remain at this value when the fused salt in which they are dipped is cooled to the point of solidification. But as the accompanying evolution of gas gradually diminishes at a lower temperature (about 350°), the potential will simultaneously change; it will diminish to the values —1.3 or —1.2 volts, etc. The gas which the carbon electrode evolves in the hot fused sodium hydrate is hydrogen gas.

If, instead of the carbon electrode, a platinum tube is dipped into the fused sodium hydrate, and pure hydrogen gas is led through it into the liquid, one obtains with a strong current of gas the potential —1.5 volts, and this will be the case at all temperatures between 500° and the point of solidification of the fused salt. The potential of the carbon in the fused sodium hydrate is, according to this, not determined directly by the carbon, but by the hydrogen which the action of the carbon on the fused salt sets free. The temperature produces no effect on the potential within the given wide range, but the rapidity of the evolution of the hydrogen is of great importance.

The authors state that thermoelectric phenomena take no part in the production of these electromotive actions. For these forces do not depend in the least on the materials iron and carbon, but only on the gases oxygen and hydrogen, and the same platinum tube shows alternately the force of the iron and the carbon electrode, if at constant temperature we pass through it oxygen and hydrogen respectively.

The Jacques cell is without importance from the practical standpoint, because during its action the valuable carbon electrode and the equally expensive sodium hydrate are changed into cheap soda, only to obtain a little hydrogen which acts electromotively. From the theoretical standpoint such a hydrogen-oxygen chain offers very much of importance. It is differentiated from the old well-known Grove hydrogen-oxygen chain, in that it is not liquid water, but a solution of water in fused sodium hydrate, which is produced by its action. The paper is concluded by a brief account of some theoretical calculations.

The discussion was opened by Prof. Burgess, who read a longer communication of Mr. C. J. Reed. Mr. Reed thinks that the authors have not given sufficient experimental evidence of their conclusions. He does not believe that there is a continual layer of iron oxide, nor does he find any explanation in the paper of the effect attributed to manganate. He remarks that the theory of the authors does not explain the fact that a current of illuminating gas passed through the cell has the same effect as air. Mr. Reed believes that Ostwald's assumption is correct that the chemical reaction is oxidation of carbon and reduction of iron oxide. If this is so, this reaction gives no e. m. f. Hence, we cannot escape the conclusion that the action of the cell is essentially thermoelectric in the sense that the electrical energy supplied by the cell has its origin in the heat supplied to the cell from the outside.

Prof. Bancroft and Prof. Kahlenberg also made two brief remarks on the paper.

The Electrochemical Series of Metals.

A paper on this subject was presented by Prof. Louis Kahlenberg, of the University of Wisconsin.

The current conception of the electrochemical series of the metals is the arrangement of the latter in a series, so that any metal will be electropositive to all that follow it, and electronegative to all that precede it; and that any member of the series will chemically replace all the metals that follow it, and in turn be replaced by those that precede it in the series. In seeking combinations of metals that would produce the highest electromotive forces, Volta discovered the possibility of arranging metals in an electrochemical series; though, as pointed out by Ostwald in his history of electrochemistry, he did not at first realize that he had thus discovered a fundamental property of the metals.

Since the time of Volta the electrochemical series of the metals has figured with more or less prominence in all treatises on chemistry and electrochemistry, and the general feeling with regard to the electrochemical series at present is that it really represents a fundamental property of the metals, and that, though the character of the electrolyte into which the metals are dipped when the electromotive forces are measured, affects the electrochemical series somewhat, such effects are but slight, and the order of the metals in the series remains essentially the same in all cases. The author thinks that Nernst's theory of solution tension has strengthened this view, but points out that experiments have shown the electrolytic solution tension of a metal to vary with the nature of the solvent.

Prof. Kahlenberg gives a review of the extended researches which have been carried out in his laboratory. The outcome of all this work is the establishment of the fact that at a fixed temperature the difference of potential between a metal and an electrolyte depends upon the character of the metal and upon the composition of the electrolyte. Not only does the character of the solvent affect this difference of potential, or, if the theory of Nernst and the theory of electrolytic dissociation be assumed, not only does the osmotic pressure of the simple ions of the metal in the solution and the so-called electrolytic solution tension of the metal determine the difference of potential, but *every* ingredient used in making up the solution affects this difference of potential to some extent, and frequently very materially indeed.

Nor would the assumption of so-called complex ions, or of an influence which the solutes might have on the concentration of the ions of the metal in question (for which assumptions there would moreover frequently be no grounds) enable one to escape from the conclusion that the electrolyte solution tension of a metal is influenced not only by the solvent, but also by the solute. But if the electrolytic solution tension of a metal is determined by the character of the solvent, and also by that of the solute, it is plainly evident that this quantity, which—according to the author—is viewed by Nernst as an inherent property of the metal itself, is in reality as much a function of all the ingredients in the electrolyte as of the metal. In this connection it is of fundamental importance to bear in mind that the change which the difference of potential between a metal and the surrounding solution undergoes when any constituent of the solution is altered, is in general different, either as to magnitude or direction, or both, for different metals toward the same solution.

The facts established experimentally point to the conclusion that the difference of potential between a metal and an electrolyte into which the metal dips is due to the mutual chemical interaction of electrode and electrolyte. The author states that on the basis of this view the facts at hand can readily be explained. It becomes clear at once why a change on any ingredients of the electrolyte should affect the e. m. f. developed, and why in the case of different metals this effect should be different as to magnitude or sign, or both, for one and the same change in the electrolyte.

At first thought it might seem that this view of ascribing the e. m. f. developed at the junction between a metal and an electrolyte to the chemical affinity, or strain tending toward interaction, existing between the metal and the electrolyte, would not enable one to detect regularities existing in the phenomena of the electromotive forces that have actually been measured, but this is a delusion. Similar metals behave similarly in the development of potential differences toward an electrolyte, and similar ingredients introduced into an electrolyte produce similar effects toward one and the same metal in the development of potential differences. Bearing this in mind, enables one to detect much of regularity in the electromotive force measured. The author gives several striking instances of how the difference of potential between a metal and an electrolyte changes when one of the ingredients of the electrolyte is gradually altered, and deals at some length with the results obtained in his laboratory by Mr. J. P. Magnusson in measurements of the differences of potential between various metals dropping in a one-tenth normal solution of lithium chloride, while the solvent was a mixture of pyridine and water in various proportions. The results are summarized in Fig. 3, where the abscissæ represent the percentage of water in the solvent (mixture of water and pyridine). In each case the chain measured was of the form metal, $\frac{n}{10}$ LiCl in pyridine, $\frac{n}{10}$ water, or pyridine + water, $\frac{n}{10}$ $AgNO_3$ in pyridine, Ag. The second half of the chain always remained unchanged; and for the value of this half of the combination the author had previously found — 0.573 volt, on the assumption that the half cell — nKCl.HgCl|Hg is equal to — 0.56 volt. The ordinates in Fig. 3 represent the difference of potential of the first half of the combination above referred to (*i. e.*, the e. m. f. of the metal against the solution of LiCl) referred to the value — 0.56 volt for the normal calomel electrode.

In the discussion which followed Prof. W. D. Bancroft remarked that Kahlenberg's results throw doubt on the correctness of some suppositions made in the thermodynamical proof of some principles of physical chemistry on which our methods of determining molecular weights are based; it seems quite certain that a semi-permeable membrane has an affinity for the liquid passing through. Dr. Patten gave an outline of the directions in which these investigations of Dr. Kahlenberg and his scholars might be extended in future. He also pointed out that measurements of potentials of aluminium

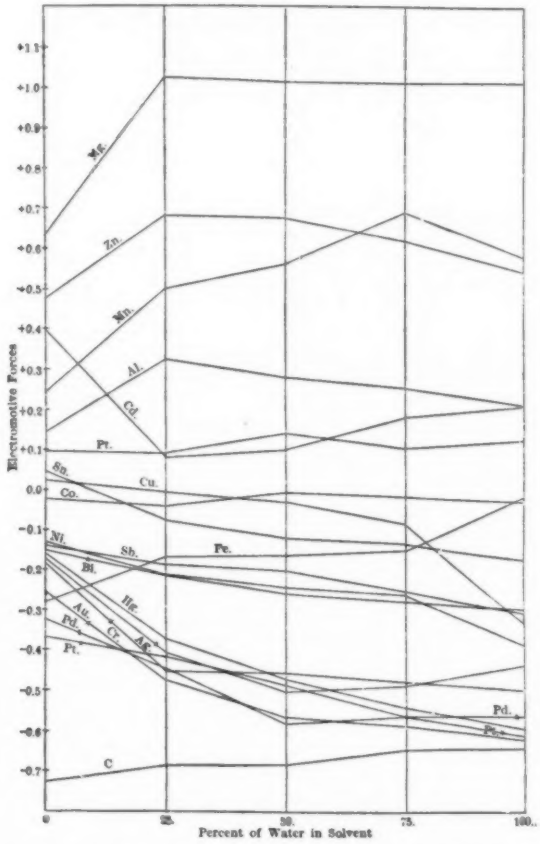


FIG. 3.—EFFECT ON E. M. P. OF VARYING PERCENTAGES OF SOLVENT IN WATER.

are generally unreliable, if not special precautions are taken. Dr. Kahlenberg agreed that the question of potentials of aluminium is quite a debatable one.

THE LEAD VOLTAMETER.

A paper on this subject, by Mr. ANSON G. BETTS and Dr. EDWARD F. KERN, was then read by Dr. Kern. The object of the paper is to describe the lead voltameter and to show wherein it possesses features which might be a means of its replacing the copper voltameter for technical purposes, such as calibrating electrical instruments and for comparison of the ampere-hour efficiency of electrochemical porcesses.

Previous to the Betts process of refining lead alloys, the crystalline non-adherent deposit which forms on the cathode in the ordinary solutions was not suited for voltametric measurements. One of the claims of the Betts patent is the formation of a smooth, dense, coherent, solid deposit of lead on the cathode in an acid solution of lead fluosilicate, which contains an organic reducing agent, such as gelatine, glue or pyrogallol, etc. It is an inexpensive solution, easily prepared, and easily maintained; it conducts the current well, is non-volatile, and is stable under electrolysis, which properties make it a suitable electrolyte for a voltameter. It also possesses the property that under ordinary conditions, when a soluble anode is used, no lead peroxide is formed, because the electrical potential required is so low, being in the proximity of 0.18 volt for concentrated solutions, and about 0.40 volt for very dilute solutions, when using a current density of 10 to 15 amperes per square foot.

The lead electrolyte was prepared by treating ordinary white quartz with commercial hydrofluoric acid (30 per cent acid) forming a solution of hydro-fluo-silicic acid (H_2SiF_6). Heating the solution of hydrofluoric acid caused more rapid solution of the quartz. White lead (basic lead carbonate) was added to the solution in the required quantity. It dissolved rapidly and completely with effervescence, and any hydrofluoric acid which did not react with the silica formed an insoluble precipitate of lead fluoride, which was filtered off. Lead fluosilicate is a very soluble salt. It dissolves in about 28 per cent of its weight of water at 20° C. The crystalline salt has the composition $PbSiF_6.4H_2O$.

The solution was diluted so as to contain 17 grams of $PbSiF_6$ and 7 grams of free H_2SiF_6 in 100 c. c. solution. After adding 1 gram of gelatine (dissolved in hot water) to 2000 c. c. solution, the electrolyte was rendered absolutely pure, in respect to metals which can deposit with lead, by electrolyzing for several days, using electrodes of refined lead. The anodes were wrapped with two thicknesses of clean linen, so as to prevent the impurities from dropping off and floating in the electrolyte. The small amount of soluble impurities in the electrolyte was due principally to the impurities in the white lead used for making the solution. The electrolysis was continued for four days at temperatures between 17° C. and 57° C., using a current density at the electrodes of 10 to 12 amperes per square foot. A small amount of "anode sludge" remained behind and in order to prevent it from being oxidized by the atmosphere and subsequently going into solution, melted vaseline was poured on the surface of the electrolyte. The deposit which formed on the cathode was smooth, dense and non-crystalline.

After purifying the electrolyte, about 800 grams of absolutely pure lead was made by electrolysis, using ordinary refined lead, wrapped with clean linen, for the anodes. The refined lead which was deposited on the cathode was further refined by reversing the current and redepositing it on new cathodes. The solution was protected from the atmosphere by a covering of melted vaseline. The purified lead was melted, cast into a thin plate and then rolled into sheets about 1/32 inch to 1/16 inch thick. The sheets were cut into strips of suitable size and used as anodes for the lead voltameter. No residue was left on dissolving the purified anodes by electrolysis.

The lead electrolyte used for the first series of experiments contained 13.5 per cent of lead fluo-silicate ($PbSiF_6$) and 6.5 per cent of free hydro-fluo-silicic acid (H_2SiF_6). It was prepared by diluting the purified electrolyte and then precipitating the excess of lead by pure sulphuric acid. The anodes were strips of the purified lead. Two glass beakers, each containing 500 cubic cms. of the electrolyte, served as voltameters. (The action of the electrolyte on glass is small and the solution in a short time loses its originally small solvent action on glass. It may be kept in glass bottles.) The two lead voltameters were connected in series with the silver voltameter, and for convenience of approximately determining the current, an ammeter was also placed in the circuit. Later on, experiments were also made with a solution containing 8.5 per cent $PbSiF_6$ and 2.5 per cent free H_2SiF_6.

The authors give details of an exact test of the lead voltameter, in comparison with the silver voltameter. In most experiments two anodes and one cathode were used; this arrangement was found to be the most satisfactory. The cathode was suspended between the two anodes and below the surface of the electrolyte by means of a thin narrow strip of metal or wire, so as to prevent the action of the atmosphere

on the lead at the surface of the electrolyte. This action may also be retarded by using an electrolyte which is less acid than that used in the experiments. Even with an almost neutral solution of lead fluo-silicate its conductivity would be sufficiently high for a voltameter.

The lead deposit, unlike the silver deposit, is smooth, dense, coherent and non-crystalline. It has a density equal to that of cast lead, so that there is no danger of losing by washing, drying and weighing. The deposit, which forms even with high-current densities (20 to 25 amperes per square foot) of cathode exposure in a fairly strong electrolyte is perfectly smooth, dense and non-crystalline, so long as the electrolyte contains about one part gelatine by weight in two to four thousand parts of solution. With age and by use, the gelatine slowly loses its reducing property. The appearance of the deposit indicates when more gelatine is needed, so that as long as the deposit forms smooth and non-crystalline none need be added. The gelatine is added by dissolving a small quantity in hot water, and adding it directly to the electrolyte. The moment it is added the crystallization of the lead is prevented.

The current density used within fairly great limits in the lead voltameter does not effect the results. In one experiment a current density of 37 amperes per square foot was employed, and the results obtained agreed as closely with the silver voltameter as when lower current densities were used. The limit of the current density seems to be controlled by the strength of the electrolyte and by its circulation. The more dilute the solution the less is the limit of current density which can be used.

The lead voltameter is well adapted for obtaining electrochemical efficiencies of experiments which require long duration. Lead has the property in common with copper in that the deposit, which forms in some electrolytes, is perfectly smooth, dense and non-crystalline. It, however, possesses some advantage over copper in that the electrochemical equivalent of lead is over three times as great as that of copper.

Of great importance is the fact that while an acid copper sulphate solution in contact with copper electrodes contains varying quantities of cuprous sulphate, lead exists in the solutions only as divalent ion. On this circumstance is founded the belief of the authors that the lead voltameter, properly used, will be found of extreme accuracy.

One advantage of lead over silver is its cheapness, so that with a small outlay a lead voltameter of any size may be constructed.

From an electrochemical point of view the lead voltameter also has an advantage over the silver voltameter in that lead stands very high in the e. m. f. series, so that the impurities which are ordinarily contained in refined lead will remain as "sludge" on the anode, whereas the purest silver is required for the construction of a silver voltameter. The results obtained by the authors show that the lead voltameter compares very favorably with the silver voltameter, as the results are within sufficient limit of accuracy for most voltametric work. In the majority of the measurements the electroequivalent weights of the lead are almost theoretical.

Differences in the amounts of lead dissolved from the anodes and deposited on the cathodes show that oxidation of lead took place to a serious extent, particularly when the solution had not had lead electrodes recently immersed in it. For accurate work the authors recommend passing a current of pure carbon dioxide through the oxygen-free electrolyte in a covered receptacle. It is also said to be desirable to use fresh polished cathodes of lead or copper each time, rather than redeposit metal on cathodes which have already been used.

The paper was not discussed.

Chlorine in Metallurgy.

A paper on this subject was presented by Mr. James Swinburne. In the absence of the author, it was read by Mr. S. S. Sadtler. Mr. Swinburne gave a brief outline of his process of treating complex sulphide ores by means of chlorine, so as to change all sulphides into chlorides, then replacing all other metals by zinc and electrolyzing the fused zinc chloride. The process has already been described at length on pages 412 and 413 of our vol. I. (August, 1903), so that the reader may be referred to this description. In his Congress paper Mr. Swinburne evidently intended to give various illustrations of his apparatus, but they were not exhibited at the meeting.

Some historical notes given by Mr. Swinburne on the process are interesting. The first patents were in 1897, and the process was tried in the laboratory and everything worked well. It was then tried on a pound scale and worked. A works was taken in Milton and large scale experiments on electrolysis of zinc chloride and handling of chlorine were carried out. A 3000-ampere electrolytic vat was run continuously for three months. Facilities were wanting there. Mr. A. J. Smith, the general manager of the Castner-Kellner Company, saw a chance of a future in the process, and the company made arrangements to put down an experimental place next door to their works. This was done and the transforming of the sulphides into chlorides was proved on a large scale. It has been claimed that the chlorine reaction does not take place, and that fused zinc chloride cannot be electrolyzed. In fact people have proved it with test tubes. The Castner-Kellner Company, however, were able to investigate the working of the process, and to inspect the transformer consuming at the rate of 30 tons a week. They were well enough satisfied with the results to arrange to take the works over, acquiring a license to make chloride of zinc. They thus use the whole process except the electrolysis, as they have a supply of chlorine from the soda works. They will run a 10,000-ampere vat for demonstration, but otherwise they will sell every metal but zinc, the zinc being sold as chloride. The only difference in the process is that zinc chloride must be much more highly refined for the market than for electrolysis, as a trace of manganese, for example, would spoil the color, but would do no harm in electrolysis. The chlorine is also damp, and has to be dried before being pumped. The Castner-Kellner Company are reorganizing the works, and reconstructing it in many details, and will probably have the first unit, dealing with 30 tons of ore a week, running this fall.

The author finally remarks that a good deal of work has been done recently on the treatment of ores with little metal content, such as copper ores running under 3 per cent, and copper, nickel and cobalt ores. These modifications have only been tried on a small scale, and so it is too soon to speak yet, but apparently low grade copper, and nickel, cobalt and, of course, their mixtures, and copper zinc ores of low content will prove amenable. Such interesting puzzles as the treatment of speiss from copper smelting works, and the smelting of antimony gold ores, have already yielded satisfactory solutions on the small scale, and fahlerz of various compositions is likely to be amenable to simple and profitable treatment.

The paper was briefly discussed. Prof. Bancroft, with reference to the notice in the paper of the Castner-Kellner Company using the process, said that electrolytic alkali plants have difficulties in using their chlorine to good commercial advantage. Mr. S. S. Sadtler remarked that while the process looks very simple on paper, yet there should be numerous great difficulties in its operation in practice.

Aluminothermics.

A special meeting of Section C of the Congress was held in the Library Hall of the Administration Building in the World's Fair on Tuesday night. Dr. Hans Goldschmidt, of Essen-Ruhr, Germany, lectured on aluminothermics. He was introduced to the audience by Dr. L. Kahlenberg. In the course of his lecture Dr. Goldschmidt made a great number of highly interesting and very effective experiments. The greater part of the lecture dealt with the uses of thermit for repairing castings and for welding rails and tubes, and with

the production of pure metals, free from carbon, by means of reduction of their oxides with aluminium. Since these subjects have already been discussed at length in our columns (especially in the two articles of Dr. Goldschmidt in our issues of November, 1903, and April, 1904), we will notice in this abstract only those points of Dr. Goldschmidt's lecture which deal with more recent developments of aluminothermics.

While speaking of the manufacture and the uses of pure metals and alloys, free from carbon, Dr. Goldschmidt remarks that ferrotitanium is being used regularly since a few years ago by several steel works. In a very peculiar way this ferrotitanium is introduced into liquid cast iron in the ladle, by means of the so-called box reaction. (See Electrochemical Industry, vol. I., p. 533.) In this way highly heated ferrotitanium is separated out at the bottom of the ladle, which alloys in statu nascendi with the content of liquid iron. The reaction taking place in the midst of the bath, the latter is more thoroughly stirred or poled than is possible by other means. Through the introduction of a small quantity of titanium, which binds the nitrogen, the composition of the bath undergoes a chemical improvement. Impurities, such as slag and others, are driven up, and the bath is further purified.

It is remarkable that the sulphur contents are appreciably reduced. The lecturer mentioned two analyses:

Cast Iron	Before Ti. addition.	After Ti. Addition.
No. I.	Mn. 0.36	Mn. 0.30
	S. 0.19	S. 0.09
	Ti	Traces.
No. II.	Mn. 0.66	Mn. 0.64
	S. 0.09	S. 0.07
	Ti.	Traces.

Of late the contents of the boxes are pressed into solid moulds, preventing the possibility of their getting unmixed and producing a perfectly regular reaction. The iron becomes considerably more fluid and it can therefore be cast at a lower temperature and will show very much less tendency to form shrink cavities. The process has been introduced in the course of the last year in a number of foundries, in particular for cylinder castings, high pressure valves, etc.

Dr. Goldschmidt then spoke of the use of "anti-piping thermit" and dealt with the use of the "box reaction" in the introduction of thermit into the risers. Formerly a small can of suitable shape was built into the bottom of the risers. Then it was considered simpler to insert the box at the end of a rod, into the liquid iron as it rose. Now in a number of works, the thermit is simply wrapped in paper and thrown on the rising liquid metal. This process is equally applied in iron and steel casting practice. For cast iron the wrapper should contain, at the bottom, a pinch of ignition powder, as the temperature of liquid cast iron is not sufficient to start the ignition of thermit. Liquid steel does not require ignition powder. Many faulty castings may be avoided by this method.

Dr. Goldschmidt then spoke of the uses of his corundum slag, obtained in every aluminothermic reaction. This artificial corundum, so-called "corubin," is very different from, and its properties are more valuable, than those of the natural product. The cause is the chemical composition of the two materials. The natural contains various impurities, such as oxide of iron, silica—even small quantities of water in chemical combination. On the other hand, the aluminogenetic corundum is nearly free from all these, and in particular absolutely free from water. This is no doubt the cause of its greater hardness compared to the natural. In consequence corubin is used for emery wheels.

A most curious and remarkable application has been made by Dr. Buchner, of Mannheim. He found that this material had an exceedinly low elastic coefficient and does not lose this property when mixed with a fire-clay binder. In this way he managed to produce vessels for chemical purposes of entirely different properties than the earthenware vessels in use up to the present. A porcelain or earthen vessel cracks very easily when exposed to even small changes of temperature. Those made of corubin behave differently. They can be heated to red heat and cooled suddenly with water without showing any tendency to crack. Dr. Goldschmidt demonstrated this by an experiment in which he heated a corubin vessel to red heat and then poured water into it; it did not crack.

Corubin offers, therefore, almost unlimited advantages to the chemical industry. Its highly refractory qualities have introduced it as a coating for bricks and tubes exposed to high temperatures. For these purposes only the corubin resulting from the chromium reaction is utilized, of which sufficient quantities are available, in consequence of the large consumption of pure carbonless chromium. This corubin requires a special preparation before being used. The aluminogenetic corubin has proved itself a valuable product for making crucibles for the thermit welding process. Such crucibles, made according to a certain recipe, will stand from fifty to sometimes 100 reactions.

After having dealt at length with the welding of rails and tubes, Dr. Goldschmidt spoke of the applications of thermit for the repair of broken castings. He mentioned that in the Russian-Japanese war thermit has played an important part, particularly on the Russian side. After the first attack of the Japanese on the Port Arthur fleet, orders for several tons were received from the Russian Government. These orders have continued to increase ever since. The remarkably speedy repairs of Russian ships were, according to accounts received by Dr. Goldschmidt, in many cases due to thermit welds. The Japanese have, of course, also used thermit, but as before the war it was less known there than in Russia, its possibilities have not received the same attention. Of course some practical experience is imperative before large quantities of thermit can be successfully handled. This experience is, however, not difficult to acquire. In far off countries thermit has been taken into constant use, although no experienced mechanics were available and the engineers had to teach themselves by closely observing the rules laid down in the pamphlets. It is just in such countries, where machinery is difficult to obtain, that thermit is of the greatest value. By its help, urgent spare castings can be made at once out of thermit steel; for instance, cog wheels.

For a special sort of repair, it is used in rolling mills for welding bosses on rolls. The surface on which the new boss is to be welded is brought to fusion heat by first pouring a little liquid iron on it, which is covered by a quantity of thermit. The latter is ignited and enables the liquid metal which is then poured on it, to evenly weld to the roll.

In conclusion, Dr. Goldschmidt mentioned an entirely novel application, appertaining to a very difficult field, namely, the "culinary." In consequence of an old suggestion, the "Deutsche Munitions & Waffenfabrik," Karlsruhe, has constructed a very handy cooking and roasting stove, allowing a speedy warming of food and drink in the open air, by means of thermit, without a flame. This may be of great value in campaigning, for instance, on outpust duty where cooking may be done without divulging one's position to the enemy.

To avoid misunderstanding, Dr. Goldschmidt emphasized that thermit cannot be adapted to firing on a larger scale, for instance, on torpedo boats or others. In this respect it cannot compete with anthracite, as one kilo thermit gives about 450 calories, anthracite about 7000. The value of the new heat producer lies in the speed of the combustion and the concentration of the heat in a very small space, not in the great number of available calorics. For heating purposes in the ordinary sense, it can therefore only be utilized on a small scale, for very specific purposes and where, besides, a particularly low price is not of importance.

There was no session either of Section C or of the American Electrochemical Society on Wednesday.

Thursday's Meeting.

The Thursday meeting was again a joint meeting of Section C of the International Electrical Congress and of the American Electrochemical Society.

The Silver Voltameter.

The first paper of the session was presented by Dr. Karl E. Guthe, of the National Bureau of Standards, Washington D. C., on the silver voltameter. The author gave a summary of the work which has formerly been done with the silver voltameter, and which led in 1893 to the adoption of the silver voltameter as a standard for measurement of electric current by the Chicago International Electrical Congress. Though the ampere was defined as one-tenth of the unit of current of the c. g. s. system of electromagnetic units, it was added, that it "is represented sufficiently well for practical use by the unvarying current which when passed through a solution of nitrate of silver in water in accordance with standard specifications, deposits silver at the rate of 0.001118 gram per second." This value is called the electrochemical equivalent of silver.

Exact specifications as to construction and use were prepared by the National Academy of Sciences and legalized in the United States in 1894. They read as follows:

In employing the silver voltameter to measure currents of about one ampere, the following arrangements shall be adopted:

The cathode on which the silver is to be deposited shall take the form of a platinum bowl not less than 10 cms in diameter, and from 4 to 5 cms in depth.

The anode shall be a disc or plate of pure silver some 30 sq. cms in area and 2 or 3 mms in thickness.

This shall be supported horizontally in the liquid near the top of the solution by a silver rod riveted through its center. To prevent the disintegrated silver which is formed on the anode from falling upon the cathode, the anode shall be wrapped around with pure filter paper, secured at the back by suitable folding.

The liquid shall consist of a neutral solution of pure silver nitrate, containing about 15 parts by weight of the nitrate to 85 parts of water.

The resistance of the voltameter changes somewhat as the current passes. To prevent these changes having too great an effect on the current, some resistance besides that of the voltameter should be inserted in the circuit. The total metallic resistance of the circuit should not be less than 10 ohms.

Method of Making a Measurement.—The platinum bowl is to be washed consecutively with nitric acid, distilled water and absolute alcohol; it is then to be dried at 160 degs. C., and left to cool in a desiccator. When thoroughly cool it is to be weighed carefully.

It is to be nearly filled with the solution and connected to the rest of the circuit by being placed on a clean insulated copper support to which a binding screw is attached.

The anode is then to be immersed in the solution so as to be well covered by it and supported in that position; the connections to the rest of the circuit are then to be made.

Contact is to be made at the key, noting the time. The current is to be allowed to pass for not less than half an hour, and the time of breaking contact observed.

The solution is now to be removed from the bowl and the deposit washed with distilled water and left to soak for at least six hours. It is then to be rinsed successively with distilled water and absolute alcohol and dried in a hot-air bath at a temperature of about 160 degs. C. After cooling in a desiccator it is to be weighed again. The gain in mass gives the silver deposited.

To find the time average of the current in amperes, this mass, expressed in grams, must de divided by the number of seconds during which the current has passed and by 0.001118.

In determining the constant of an instrument by this method, the current should be kept as nearly uniform as possible and the readings of the instrument observed at frequent intervals of time. These observations give a curve from which the reading corresponding to the mean current (time-average of the current) can be found. The current, as calculated from the voltameter results, corresponds to this reading.

The current used in this experiment must be obtained from a battery and not from a dynamo, especially when the instrument to be calibrated is an electrodynamometer.

The author then gave a long, but concise summary of the experimental researches which have been carried out by various investigators on the reactions in and the construction of the silver voltameter. He remarks that the greatest advance in our knowledge of the subject is due to the researches of Richards and his students, who showed that the main difficulty lies in the formation of a heavy anode solution, containing a complex silver ion. The anode solution which in the ordinary type of voltameter sinks to the bottom of the vessel, producing there a star-shaped figure, will yield on electrolysis more silver than corresponds to the normal ion. Besides, this substance, formed at the anode, must be a reducing agent, since oxygen tends to eliminate it. The exact chemical constitution of the substance is not known.

The main problem is to prevent the anode solution from reaching the cathode. For this purpose Richards places the silver rod, which forms the anode, in a fine-grained porous cup and removes from time to time the solution collecting at the bottom.

Guthe fully corroborated Richards' results, but proposed a different form of the anode. The bottom of a wide porous cup is filled with granulated silver and upon this a large silver plate is pressed. In this type the rather inconvenient frequent removal of the solution was found to be unnecessary. The heavy solution is prevented by the porous cup from rapid diffusion and breaks up to a large extent when it remains in contact with silver. This secondary reaction, he believes, gives rise to the formation of the well-known dark anode slime, which is pure silver when the anode is pure.

Other arrangements may be adopted to prevent the anode solution from reaching the cathode. The latter may, for instance be suspended above the anode, or the two electrodes be placed in different vessels, connected by a siphon. From a practical point of view the latter types are, however, less convenient than the two described above.

Filter paper should not be used in the preparation of the electrolyte nor in the voltameter, since it contains organic substances which may act chemically upon the solution.

As Guthe has shown, we can distinguish two distinct types of silver voltameters, according whether the heavy anode solution reaches the cathode or not. The former to which the ordinary type and those proposed by Patterson and Guthe and by Leduc belong will on the average yield a deposit one part in 2000 larger than in the second type. Of course, for practical purposes we must select the type which will give the most concordant results. As investigations show, we can rely upon the porous cup voltameter to within one part in 20,000, even for independent series of experiments; it would, therefore, be a decided step in advance, if one of these types were substituted for the one now in common use. This would, however, necessitate a change in the accepted value of the electrochemical equivalent of silver.

The author then summarizes the results of many investigations concerning a great number of details in the construction of the voltameter and finally deals with determinations of the electrochemical equivalent of silver.

TABLE I.

Observer.	Year.	Voltameter.	Method.	Electro-chemical Equivalent	
				Found.	Corrected
				mg.	mg.
Mascart[1]	1884	Usual type. ..	Current balance	1.1186	1.1180
Fr. and W. Kohlrausch	1884	"	Tangent galv	1.1183	1.1177
Rayleigh and Sidgwick	1884	"	Current balance	1.1179	1.1173
Gray	1886	Plate voltameter	Sine galvan	1.1183	1.1177
Koepsel[2]	1887	Usual type	Current balance	1.1174	1.1168
Pellat and Potier[3]	1890	"	"	1.1192	1.1186
Patterson & Guthe	1898	Silveroxide type	Electrodynamometer	1.1192	1.1182
Pellat and Leduc[4]	1903	Leduc's type	Current balance	1.1195	1.1188
van Dijk & Kunst[5]	1904	Usual type	Tangent galv	1.1182	1.1176

[1] Mascart, *Journ. de Phys.*, vol. 2, p. 109, 1883 and vol. 3, p. 283, 1884.
[2] Koepsel, *Wied. Ann.*, vol. 31, p. 250, 1887.
[3] Pellat and Potier, *Journ. de Phys.*, vol. 9, p. 381, 1890.
[4] Pellat and Leduc, *C. R.*, vol. 136, p. 1649, 1903.
[5] van Dijk and Kunst, *Ann. d. Phys.*, vol. 14, p. 806, 1904, *Proc.* Kon Ak. van Wet, vol. 12, p. 141, 1904.

The electrochemical equivalent of silver has been determined repeatedly by absolute measurements, *i. e.*, by means

of instruments which allow a calculation of the current in terms of the fundamental units of mass, length and time. Among the earlier investigations only those of Rayleigh and Mrs. Sidgwick, and of Fr. and W. Kohlrausch can be considered accurate. In order to express all measurements in terms of the same standard, the different values found have been reduced by the author to those given by the porous cup voltameter, and these are given in the last column of the following table. The corrections used are those found by Richards and Guthe for the various types. Since, in most cases the exact conditions of the experiments are unknown, these corrected values will simply give a general idea of the agreement between different observers; therefore, it was thought unnecessary to take into account the possible effect of included mother liquid.

From this list it is seen that the results obtained so far are not very satisfactory. Redeterminations in absolute measure by using a reliable form of voltameter are highly desirable.

The electrochemical equivalent of silver may also be expressed in terms of the electromotive force of the standard cell, *i. e.*, by comparing the electromotive force of the cell with the potential difference produced by the current at the terminals of a known resistance. The electrochemical equivalent will depend upon the value chosen for the electromotive force of the standard cell. The legalized value for the Clark cell is 1.434 volts. But this is probably too high. In Germany the electromotive force of the Clark cell is derived from silver voltametric measurements, and the Reichsanstalt has chosen as the working value 1.4328 volts at 15° C. In the following table the electrochemical equivalent of silver is calculated, as well for an electromotive force = 1.434 as for 1.433 volts:

TABLE II.

Observer.	Year.	Electro-chemical Equivalent.			
		E = 1.434 Volts.		E = 1.433 Volts.	
		Usual Type.	Porous Cup V.	Usual Type.	Porous Cup V.
		mg.	mg.	mg.	mg.
Carhart[1]	1882	1.1172	1.1167	1.1180	1.1175
Rayleigh and Sidgwick	1884	1.1183	1.1178	1.1192	1.1187
von Ettinghausen[2]	1884	1.1180	1.1175	1.1188	1.1183
Glazebrook and Skinner	1892	1.1183	1.1178	1.1191	1.1186
Perot and Fabry[3]	1898	1.1193	1.1188	1.1120	1.1196
Kahle	1898	1.1173	1.1167	1.1180	1.1175
Guthe	1904	1.1174	1.1168	1.1181	1.1176

[1] Carhart, *Am. Journ. Sci.*, vol. 28, p. 374, 1884.
[2] Von Ettinghausen *Zeit. f. Electrotechnik*, vol. 2, p. 484, 1884.
[3] Perot and Fabry, *Ann.* Fac. des Sci. Marseille, vol. 8, p. 201, 1898.

In the case of Perot and Fabry, who used a Clark cell at 0° C. and found its electromotive force to be 1.4522 volts, using 1.118 mg. as the electrochemical equivalent, the difference of 0.0164 volt given by the Reichsanstalt has been used to reduce to 15° C., instead of the ratio given by them. The latter would give 1.1180 mg. in the first column and corresponding values in the others, and make the agreement with the earlier experiments a very close one.

The large differences between the earlier and the more recent comparisons can hardly be due to the silver voltameter alone. Doubtless the Clark cell comes in for its share.

Dr. Guthe concluded by emphasizing that as far as accuracy and the possibility of exact reproduction of the instrument are concerned, the silver voltameter is as good a standard instrument as a standard cell; however, the latter may win out finally for practical reasons.

The paper elicited an animated discussion. Dr. R. T. Glazebrook emphasized that in using the results of former investigators, one should always take into account the special form of voltameter used by them; he then gave a summary of recent work done in this field by the (British) National Physical Laboratory. Dr. W. D. Bancroft suggested to try the use of a revolving cathode inside a porous cup; the method works admirably for analysis and permits the use of much higher current densities than were formerly employed; why should it not be useful for the voltameter? In a reply to a question of Mr. S. S. Sadtler how silver nitrite behaves as electrolyte, Dr. Guthe said that he never used it. Prof. H. S. Carhart spoke of his early experiments with the silver voltameter and expressed the belief that it is not as good as a standard cell.

A Study of the Materials Used in Standard Cells and Their Preparation.

A paper on this subject was then read by Prof. Henry S. Carhart, of the University of Michigan; it consists of two parts, the first part, by Prof. Geo. A. Hulett, dealing with the chemistry of mercurous sulphate and its preparation for use in standard cells, the second part, by Prof. Henry S. Carhart, giving exact instructions for the preparation of the various materials and the construction of standard cells. A preliminary account of these investigations, given in a former paper of Prof. Carhart, has already been noticed in our May issue, 1904 (vol. II., page 176).

The preliminary work with Hg_2SO_4 consisted in testing various samples from the point of view as their use as a depolarizer. In each leg of an H cell was placed mercury, and the cell was then filled to above the cross-bar with dilute H_2SO_4; with mercurous sulphate on the mercury there was no e. m. f., provided the Hg_2SO_4 in each leg was from the same sample, but different samples generally gave an e. m. f. Electrolytically prepared Hg_2SO_4 was taken as standard and all others compared with it. Preparations of well-known makes differed markedly often by 0.001 volt.

Dr. Hulett dealt at some length with the equilibrium between mercuric ions, mercurous ions and metallic mercury. Since there is relatively little mercuric mercury in a solution which is in equilibrium with mercury, and since the mercuric sulphate is more soluble than the mercurous, then if we bring the system Hg-salt-solution to equilibrium, the salt cannot contain mercuric sulphate, but will be only mercurous sulphate.

Dr. Hulett then deals at some length with the hydrolysis of Hg_2SO_4, which takes place as follows:

$$3Hg_2SO_4 + 2H_2O = (HgOH)_2Hg_2SO_4 + 2HgHSO_4.$$

A liter of water hydrolyses 1.75 gm. Hg_2SO_4 leaving 0.90 gm. of $(HgOH)_2Hg_2SO_4$ as a residue while 0.68 gm. $HgHSO_4$ go into solution. This hydrolysis must be strictly avoided with standard cells, and Dr. Hulett gives the results of experiments as to the concentration of sulphuric acid which would prevent hydrolysis.

The rules as to the preparation of mercurous sulphate, based on Dr. Hulett's results, are given by Prof. Carhart as follows: In a flat-bottomed glass vessel (Fig. 4) is placed pure mercury about 2 cms. deep. It is covered with dilute sulphuric acid to a depth of 8 or 10 cms. The acid is prepared by adding one part by volume of concentrated H_2SO_4 to six parts of distilled water. Hydrolysis of mercurous sulphate does not take place in the sulphuric acid solution of this concentration. The solution is electrolyzed by making the mercury anode and a piece of sheet platinum hung in the acid the cathode. A current density of about 0.5 ampere per 100 square cms. surface of mercury may be employed. As soon as the current begins to flow a crystalline mercurous sulphate forms. A stirrer, consisting of a glass rod bent at right angles at the bottom, must be used to keep the surface of the mercury exposed and to stir the solution and the salt formed; it should be driven rapidly by a motor. A little over 4 grams an hour can be prepared in this way with a current of half an ampere. The apparatus should be kept covered with black paper or black cloth, since mercurous sulphate darkened by exposure to light gives too high an e. m. f. If the stirring is continued after the circuit is broken, the crystals of mercurous sulphate increase in size and become whiter. The mercurous sulphate may be removed from the mercury by means of a separatory

funnel, but it should be kept under the 1 to 6 acid solution, in contact with mercury, and in the dark.

Prof. Carhart also gives exact instructions on the preparation of the other materials used in standard cells, and on the method of setting them up (see our May issue, page 176). He also gives the results of a great many tests of cadmium cells. The e. m. f. of the Weston cadmium cell, with electrolytic mercurous sulphate, after equilibrium is reached, is 1.01907 or 1.01908 volt at 21.1° C. The agreement between the various cells, after electrical equilibrium is reached, appears to be excellent. In the discussion which followed, Dr. T. R. Glazebrook referred to experiments made in the (British) National Physical Laboratory; they have experimented with three different methods of preparing mercurous sulphate; one of these is Carhart's method; the three methods appear to yield

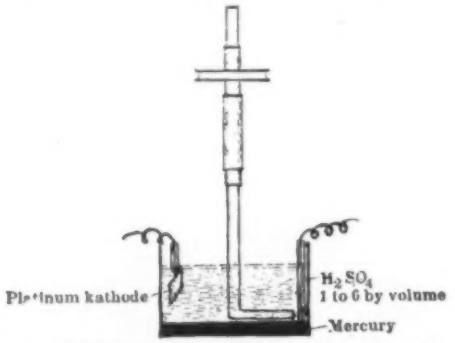


FIG. 4.—ELECTROLYTIC PRODUCTION OF MERCUROUS SULPHATE.

identical results. (See an abstract on this subject in the Synopsis of Articles in Other Journals, in this issue). Prof. Bancroft pointed out that this work of Carhart and Hulett shows that we have here a strictly reversible electrode. There exists experimental evidence tending to prove that the calomel electrode is not strictly reversible, although it is generally used as such. The maximum surface tension method ("Tropfelektrode") does not give us true single potential differences.

Electrometallurgy of Iron and Steel.

A paper on this subject was then presented by Dr. Paul L. T. Heroult, of La Praz, France. In the introduction the author pointed out that many inventors have proposed processes in this field, but that some of these processes are only theoretical conceptions, more or less practical, but existing only on paper. Commercial results furnish the best criterion, and from this point of view, the author says, the Société Electrometallurgie Française de Froges is the only concern which has, during the last two years, really manufactured and put on the market a complete series of carbon steels of a quality equal to or better than the best tool steels known.

The author makes a few remarks on his manufacture of ferrochrome. The walls of the crucible are made of ferrochrome ore, and two electrodes drop into the slag above the bath. The metal thus never comes into contact with carbon. Thus, the reducing carbon being exactly proportioned, it is possible to obtain soft metals, that is to say, metals almost entirely free from carbon.

Concerning the reduction of iron ores and the manufacture of steel he says that it would not be advantageous to perform the different operations—reduction of the ore and refining of the metal—in one and the same apparatus. First, pig iron is made in a special electric crucible. This operation takes place without any special difficulty, providing the indispensable precautions be taken in the arrangement of the charge and in carrying out the operation.

In a general way, the author points out, it is not advantageous to transform electrical energy into heat for the reduction of a so easily reducible ore as iron. Since electric heat is very costly, it must be economized to the fullest extent. Dr. Héroult refers to two means of economizing the electric heat. One is his "economizer." This device is based upon the principle of combining the total amount of oxygen contained in the ore with carbon to CO. This CO is subsequently burned by admitting the necessary amount of atmospheric air. The heat generated in this last operation is used to heat the ore previous to its reduction. As a matter of fact, this ore falls into the reduction chamber in the molten state. The amount of electric energy necessary for carrying out the operation is theoretically nil, although in the experiments made in practice it amounted to quite a considerable quantity, on account of losses by radiation. This process did not prove entirely satisfactory, owing to the great difficulty of preventing the walls from corroding, and also to the consumption of the reducing carbon which is large.

The second process described by Dr. Héroult and stated to have been successful, consists in reducing one-half of the ore in the molten state, while the other half is reduced in the solid state by means of the CO evolved by the first half. "If one makes the calculation of the heat units absorbed by the reduction and the heat units evolved by the burning of the carbon in the form of CO_2, one can easily perceive that the quality of electricity needed is very small."

Dr. Héroult then said he would not further discuss the manufacture of pig iron, "because the electric process, though very interesting, is only applicable under certain conditions, and is not likely to supersede the blast furnace, except where electrical energy is extremely cheap." He then discussed his electrical steel process. This process, which is worked at La Praz, France, and at Kortfors, Sweden, produces steel stated to be of a quality equal to and superior to the best crucible cast steel. The quality of the raw material from which it is made, is a matter of indifference. For instance, steel containing about 0.01 sulphur and 0.01 phosphorous is being made out of raw materials, scrap, that contains 0.15 sulphur and 0.30 phosphorous. The electric furnace has enabled the metallurgist to get rid once for all of the necessity of choosing beforehand his raw material and paying for it a high price. The de-phosphorizing of metals was well understood, although the facilities afforded by the electric furnace are such that it was rendered possible to attain in one operation the results above referred to. The process of desulphurization, which, up to the present time has always been considered unsafe and erratic has been brought by Héroult to a high degree of perfection. By means of the electric furnace he has the entire operation in perfect control. He can regulate the temperature as he chooses and carry out the work without any oxidation from the air.

He makes the claim that at a cost not exceeding one-half a dollar a ton, he can make out of any steel delivered in the molten state, that is, as tapped out of a Siemens furnace or a Bessemer converter, a metal of any desired composition, containing less than 0.01 sulphur and 0.01 phosphorus. The electric process must not be considered as a steel-making process, but as an adjunct to existing plants and apparatus. By means of this electrical adjunct the commercial value of the product can be greatly increased.

The author says, there will be in future no excuse for not making steel free from impurities such as sulphur and phosphorus. He is far from predicting that the electrical furnace process will supersede the old metallurgy, but "it will and must cause a revolution so far as the quality of the metal used in the industries is concerned." (Concerning details of the Héroult steel process the reader may be referred to descriptions on pages 63, 287, 449 and 467 of vol. I. of this journal.)

In the discussion which followed the paper, Prof. J. W. Richards spoke quite enthusiastically on Dr. Héroult's work. He pointed out that when we consider the finer grades of steel which are very expensive at present, the cost of the electric refining process is of little account. He predicted that

industrial developments in this field will soon set in, first in Canada and then in the United States. The electric furnace will then be used as an adjunct to the open-hearth furnace, to take off the peak of the load, *i. e.*, to furnish electrically the last few hundred degrees to bring the metal to the melting, point while the combustion of gas furnishes the lower range of temperature. We are now in a period of transition in the steel industry.

Mr. Woolsey McA. Johnson said that the only criterion of a successful metallurgical process is its operation on a large scale, as accomplished in the case of Héroult. The use of the electric furnace for refining steel is another example of the general rule, that in metallurgy electrochemical methods are specially useful for the finishing reactions. Mr. Edstrom spoke briefly on the suitability of the process for Sweden, with its abundance of water-power.

THE PRESENT STATUS OF THE EDISON STORAGE BATTERY.

A paper on this subject, by Prof. A. E. KENNELLY and Mr. S. E. WHITING of Harvard University, was "presented on behalf of Mr. Thomas A. Edison, as a brief synopsis of the results obtained with his storage battery up to the present date." It was read by Mr. Whiting.

The authors give some historical notes on the development of the battery and especially on the so-called types C, D, E, of which E is the latest one. E-18 has 12 nickel plates and 6 iron plates. The weight of this cell complete is 12.66 lbs. (5.75 kilos). The normal rated delivery of these cells is 114 ampere-hours, which is practically the same at either the 30-ampere or 120-ampere discharge rate. At the 30-ampere rate (3.8 hours), the mean potential difference to 0.75 volt is 1.234 volts, representing an output of 141 watt-hours or 11.1 watt-hours per pound (24.6 watt-hours per kilo). At the 120-ampere rate (0.95 hour), the mean potential difference to 0.75 volt is 1.04 volts, representing an output of 118.5 watt-hours or 9.38 watt-hours per pound (20.7 watt-hours per kilo). Although the above are the normal rated capacities, the full capacity of the cell is found to be about 140 ampere-hours, which makes the total output at 30 amperes, 173 watt-hours and at 120 amperes 145 watt-hours; or the specific output 13.7 watt-hours per pound (30.2 watt-hours per kilo) and 11.5 watt-hours per pound (25.4 watt-hours per kilo) at the two rates, respectively.

The authors then give some details on the construction of the cells of type E (see ELECTROCHEMICAL INDUSTRY, January, 1904, vol. II., page 36). The cell is now manufactured in three sizes stated in table III.

The authors discuss briefly the chemical theory of the cell and then describe the discharge curve of e. m. f. which has the following peculiarities:

(1) An initial period of rapid descent occupying about 10 per cent of the delivery period.

(2) A nearly steady gradient of gradual descent continuing until within about 10 per cent of the end of the whole delivery period.

(3) A final period of rapid descent occupying the last 10 per cent of the delivery period (assumed as stopping at a potential difference of 0.75 volt).

The initial e. m. f. is influenced by the previous history of the cell, more particularly by the time which has elapsed since the close of the preceding charge. The range of initial e. m. f. is between 1.35 and 1.65 volts. It would seem that this e. m. f. depends upon the amount of gases remaining after the charge, occluded in the pores of the cell.

The e. m. f. at and near the end of the discharge is also somewhat variable, depending in some measure upon the rate and nature of the discharge. It clearly accompanies the exhaustion of the active materials.

In the intermediate stage of the discharge, the gradient of descent is substantially uniform and approximately independent of the discharge rate within the usual working limits. This diminution of e. m. f. may possibly be due to the increasing thickness of the layer of effete material formed by the progressive exhaustion of the active material.

If the curve *a b c d* (Fig. 5) be integrated, the mean ordinate is found closely to approach the actual ordinate at *C* or the point of half delivery. This means that a straight line *A C D* may be chosen nearly coinciding with the steady gradient of the actual curve *bc*. This is shown in a dotted line *A C D* in the figure. The area above this line *A a b* at the beginning, is approximately equal to the area below the line *c D d* at the end. These areas represent, therefore, sensibly equal and opposite quantities of electrical energy, with respect

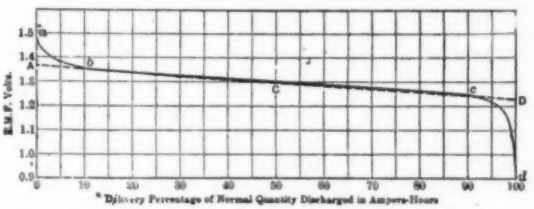


FIG. 5.—DISCHARGE OF EDISON BATTERY

to the curve *a b c d*. Consequently, we may for practical purposes replace the actual curve *a b c d* by the equivalent straight line *A C D*, which is represented by the formula

$$e = 1.37 - \frac{x \times 0.14}{100} \text{ volts}$$

where x is the percentage already yielded, of the full delivery. The mean discharge e. m. f. is, therefore, 1.30 volts. This approximation greatly simplifies practical computation with the Edison battery.

The internal resistance of an Edison Type E cell is substantially constant during the main working portion of the discharge corresponding to *bc* in Fig. 5. Thus in the E-18 cell, the internal resistance at ordinary temperatures is about 0.0022 ohm. This would correspond to 0.0278 ohm in a Type E similar cell weighing one pound; or to 0.0126 ohm in a cell weighing 1 kilo. The internal resistance is slightly less at the beginning of the discharge, but becomes considerably greater near the end of the discharge. Since, however, this rise in resistance occurs only during a small portion near the end of the delivery, its effect in the total discharge may be neglected for most practical purposes.

The internal resistance does not vary greatly with the discharge rate within the usual working limits of 0 to 150 amperes. In other words, the drop of pressure in the cell is approximately proportional to the discharging current strength.

The maximum amount of power which may be obtained

TABLE III.

Type.	Positive Plates.	Negative Plates.	Capacity in Ampere-Hours.		Normal Charging Current. Amp.	Normal Charging Time. Hours.	Weight Complete in Kilograms.	Dimensions over all (Excluding Trays).			
			Normal.	Maximum.				Length in Cms.	Breadth in Cms.	Height in Cms.	Volume in Cubic Cm.
E-18	12	6	110	140	40	3.75+	5.66	13.0	6.6	33.5	2,874
E-27	18	9	165	210	60	3.75+	7.95	13.0	..	33.5	....
E-45	30	15	275	350	100	3.75+	13.6	13.0	..	33.5	....

from a cell in an external circuit is obtained if the resistance of the external circuit equals the internal resistance of the cell. For an E-18 cell this condition of maximum power corresponds to 15.15 watts per pound (33.4 watts per kg.), corresponding to a discharge rate of 296 amperes (less than half an hour). The practical rate of power delivery at 150 amperes corresponds to 11.5 watts per pound (25.4 watts per kg.), which is on a par with the full-load output of good dynamo machines.

The energy liberated in an E-18 cell is 1.3 volts × 141 ampere-hours = 183.3 watt-hours or 14.48 watt-hours per pound (31.9 watt-hours per kg.) and this liberation of energy is constant to a first approximation for all rates of discharge within the working limits. The amount of this liberated energy which is delivered in the external circuit depends only on the electrical efficiency of the circuit, or on the drop of pressure in the cell. Thus, at 90 per cent electrical efficiency, or 10 per cent internal drop (corresponding to about 60 amperes in the E-18 cell), the externally delivered energy would be 183.3 × 0.9 = 165 watt-hours.

It can be shown that if any Edison Type E battery, in any grouping of cells, be discharged at the rate of p watts per unit mass, reckoned at the mean voltage of discharge, the electrical efficiency, of the battery circuit will be $\frac{1+\sqrt{1-n}}{2}$, where $n = \frac{p}{P}$ and P is the maximum power per unit or mass or $\frac{e^2}{4mr}$, where m is the mass of a cell, e the actual e. m. f. and r the internal resistance.

Thus, if a battery of 68 Edison Type E-18 cells be discharged at 120 amperes or 124.3 average external watts, the total external power will be 68 × 124.3 = 8454 watts, and the total weight being 861 pounds, the power rate per pound taken from the battery is 9.83 watts. The maximum power rate is, however, 15.15 watts per pound as above; so that the ratio $n = \frac{9.85}{15.15} = 0.65$. The electrical efficiency of the battery circuit is, therefore,

$$\frac{1+\sqrt{1-0.65}}{2} = 0.796$$

or 79.6 per cent. The delivery per pound of battery will, therefore, be 14.5 × 0.796 = 11.5 watt-hours per pound, and the entire battery will deliver 9900 watt-hours to the external circuit, when discharged to 0.75 volt potential difference per cell.

The charging e. m. f. of an Edison cell is approximately 1.6 volts (somewhat greater at the outset) until about 60 per cent of the charge has been stored, when it rises to about 1.75 volts, simultaneously with increased evolution of gases. This rise is, therefore, apparently connected with gaseous polarization. To the e. m. f. of the cell must be added the drop in internal resistance, in order to find the potential difference at charging terminals. The mean e. m. f. of the cell during charge may, therefore, be taken as roughly 1.67 volts. The resistance of the cell during charge is approximately the same as during discharge, being greater at the outset of the charge, corresponding to the condition of resistance at the end of the discharge.

During the charge of Edison cells, bubbles of gas are liberated at both plates, oxygen at the anode or positive plate, and hydrogen at the cathode or negative plate. The collected gases form an explosive mixture. In the ordinary charging process there is a distinct evolution of gas at the outset, which reaches its maximum in about a quarter of an hour. The gassing then decreases to a lower steady value, which continues until about 60 per cent of the charge, after which it rapidly rises to a steady much higher value than at first. The electrical energy expended in the liberation of these gases is practically all lost.

To replace the water thus lost by decomposition during charging, a small quantity of distilled water has occasionally to be added to the cells through a filler conveniently adapted to this purpose.

Since the mean electromotive force of discharge is approximately 1.3 volts, and the mean electromotive force of charge approximately 1.67 volts, it follows that the superior limit of watt-hour efficiency in an Edison cell is $\frac{1.3}{1.67}$ or 78 per cent. In practice it is always less than this, due to internal drop.

The efficiency may best be examined first in relation to the voltage of charge and discharge, and second, in relation to the electric quantity charged and discharged.

1. If there were no drop of pressure due to internal resistance, either in charging or in discharging, and all the electricity charged in the cell (as expressed in coulombs or ampere-hours) were discharged, the ampere-hour efficiency of the cell being thus 100 per cent, the watt-hour efficiency would be 78 per cent or thereabouts. This figure can, in fact, be approached by employing very low rates of charging and discharging; *i. e.*, by taking many hours to each process. On the other hand, the more rapid the charge and discharge, the greater the IR drop in the cell, and the less the efficiency, even on the assumption of 100 per cent ampere-hour efficiency. Thus at 60-amperes charging and discharging rates, the potential difference in charge would average about 1.8 volts in the E-18 cell and the potential difference in discharge would average about 1.17 volts to the 0.75 volt limit, representing a watt-hour efficiency of 65 per cent, with 100 per cent ampere-hour efficiency.

2. The Edison cell would manifestly possess an ampere-hour efficiency of 100 per cent if no gases or irreversible substances were generated in its cycle of chemical action. Thus if a certain number of grammes of iron were reduced and a certain number of grammes of nickel were oxidized by one ampere-hour of charging current, and no other action took place, then on discharge the reconversion of these masses of active material would develop the complete ampere-hours of electricity. On the other hand, every gramme of hydrogen (or the equivalent mass of oxygen) liberated and discharged from the negative plate during charge absorbs 26.8 ampere-hours of electricity, which is not returned to the circuit during discharge. The ampere-hour efficiency of the Edison cell is, therefore, determined by the amount of gas escaping during the charge. This in turn depends upon the rate of charge, or charging-current strength, since the greater this strength the greater the drop in internal resistance, and the sooner the plates are brought to that difference of potential at which the water is rapidly decomposed.

At high rates of charge, then, the watt-hour efficiency of the cell must fall off, not only because of the voltage drop, but also on account of the reduction of ampere-hour efficiency in gasification.

Nevertheless, in many cases, and particularly in automobile work, this sacrifice of energy is amply warranted by the convenience and saving of time effected by rapid charge. The normal charging time of Edison E cells is about four hours. In cyclical charges and discharges of four hours each, the ampere-hour efficiency is about 75 per cent and the voltage ratio 70 per cent, so that the watt-hour efficiency may be taken in round numbers at 50 per cent (0.75 × 0.7 = 0.525). It is possible, at a still greater sacrifice of efficiency, to charge the cell at fully double the above normal rate.

The authors then give a summary of the results of various tests of the Edison battery, mostly made abroad; these results have already been given in our columns (v. II., p. 40, 118). It is also stated that much experience has been attained in actual service from the Edison battery on automo-

biles, and that this experience has led to the elimination of some of the minor practical difficulties that any new battery always encounters. It is stated that the Edison battery appears to be so durable that no electrical depreciation is discernible in the cells during the three years' total experience of the practical construction of the battery. No mechanical corrosion of the plates or pockets has been discernible during that time and no depreciation seems to have yet occurred in the active material, judging from the capacity tests of cells which are stated to be as great at the present time as they were when the cells were first constructed. The authors have recently confirmed this observation in the case of Type D cells that have run nearly 3000 miles in an automobile of the Edison Company in Boston. The capacity of these cells was found to be equal to that of new cells of the same type. Two of these cells were opened for examination and the sediment in them collected and dried. The dry sediment weighed 3.9 and 7.1 grams respectively, probably less than one-third of 1 per cent of the active material in the grids. In fact, a new cell freshly set up will show about this quantity of material washed by the solution from the external surface of the plates. No signs of depreciation or corrosion appeared on any of the plates or connections.

According to observations at the factory, Edison cells lose 15 per cent of their ampere-hour charge in eight weeks of idleness; somewhat different figures have been obtained in other tests. But all tests show that the cells are remarkably immune from deleterious effects due to careless treatment. Cells have been allowed to dry out, have been permanently short-circuited or even charged in the wrong direction. These cells have shown a full restoration of their capacity after a prolonged restoring normal charge.

The conclusions reached by the authors are that "the Edison nickel-steel alkaline storage cell, in its large output at heavy discharge rates, its low depreciation in capacity and its durability under severe and adverse treatment, approaches the capabilities of a piece of mechanical apparatus more nearly than is ordinarily credited to electrolytic structures. For this reason it is specially adapted to automobile service, where the treatment is abnormally arduous and severe."

In the discussion which followed, Prof. C. F. Burgess gave the results of some tests made by two of his students in his laboratory in the University of Wisconsin on Edison cells taken from automobile service; the efficiencies obtained were below 50 per cent; attention was also called to the fact that gas is also developed during the discharge of the cell. Dr. A. E. Kennelly pointed out that in the Edison cell an approach is made to the steel structure in dynamo construction. We have here a steel structure which resembles the steel structure in machines devoid of electrolyte, the figures of power per weight being of the same order of magnitude as for good dynamos. The battery has a low efficiency, but it has the great advantage of being nearly fool-proof. Replying to a question of Mr. S. S. Sadtler, Mr. Whiting described how the cell is practically sealed so that no air can reach the electrolyte, which would result in the formation of carbonate.

Electrolytic Conduction.

A paper on this subject was then presented by Prof. Joseph W. Richards, of Lehigh University, who, in his introductory remarks, said that it is sometimes good to go back to fundamental principles; his paper is intended to reconsider the problem of the mechanism of the conduction of the electric current through electrolytes. According to the ionic hypothesis, electrolytic conduction is *per se*, in the body of the electrolyte, different in nature or kind from metallic conduction, in which we know that there is no migration of ions or carrying of the current by the convective action of charged ions.

The object of Dr. Richards' paper is to present the thesis that, as far as the conduction of electricity through the body of the conductor is concerned, there is, as far as we can determine, complete identity between metallic conductors and so-called electrolytic conductors.

After having referred to Marvin's experiments on induced currents in electrolytes without the use of electrodes and on Richards' and Landis' experiments on the electrolysis of sulphuric acid solutions with very small currents, the author presents the following argument. Many solid chemical compounds are conductors of electricity; in fact, the majority are. They are, in this condition, undoubtedly conductors in the ordinary sense of possessing metallic conductivity. No scientist ascribes a different kind of conductivity or a different mechanism of conduction to a solid copper bar from a liquid column of mercury. In fact, liquid mercury is used as the standard of resistance of metallic conductors. There is no sharp change in electrical conductivity when a metal melts, which again points to the identity of metallic conduction through solid or liquid metals. Similarly, there is no sharp change in conductivity when a solid conducting salt melts; it becomes a liquid conductor at the melting point without change in conductivity, just as metals do. The conclusion is that there is conductivity of the same nature in a fluid salt as in a solid salt, and as in a metal, viz., metallic conduction.

Since a solid salt conducts metallically, and a fused salt electrolytically; that is, with accompanying electrolysis, the author concludes that if the mechanism of the conduction through the body of an electrolyte is mere metallic conduction and nothing else, then, the electrolysis is a thing apart from the mechanism of the conduction. He, therefore, claims that the electrolytic or electro-chemical phenomena accompanying the passage of the current are matters occurring only at the electrodes, and have no rational connection with the mechanism of the transmission of the current through the body of the electrolyte.

Dr. Richards then describes the following experiment. A narrow glass tube about 12 inches long is turned up at the ends, so as to leave about 6 inches straight tube in the middle. It is warmed, and melted zinc chloride (M. P. 262° C.) poured into it. A Bunsen burner is kept under the middle, to keep it melted, and two zinc rods are plunged into the melted salt in the upturned ends, where the salt at once sets. The cell is now constituted as follows: Zinc—Solid $ZnCl_2$ — Melted $ZnCl_2$ — Solid $ZnCl_2$ — Zinc. Asbestos screens are slipped over the tube so as to define sharply the boundary line between solid and fused salt.

When the temperature is steady for some time, a thermopile is connected with the terminals, a delicate galvanometer reading to microamperes being put into the circuit. The following facts were established: (1) For e. m. f.'s up to 3.5 volts, the current passing is proportional to the applied e. m. f. (2) On removing the impressed voltage, there is no trace of back e. m. f., in any case. (3) On continuing a current of 50 to 100 microamperes 15 minutes, there is no trace of electrolysis, either by the formation of gas or metallic deposit or "metallische Schliere" at the junction of the liquid and the solid electrolyte or at the metallic terminals.

The experiment proves to the author, taking it in connection with the preceding observations, that the liquid salt acts merely as a simple conductor of the same nature as metallic conductors, and by a similar mechanism, and that the question as to whether electrolysis or electrochemical action takes place is a matter entirely independent of the mechanism of electric conduction through the body of the electrolyte. At any rate, the passage of electric current from solid zinc to solid zinc chloride, or *vice versa*, or from solid zinc chloride to fused zinc chloride, or *vice versa*, is not one of the conditions which produce electrochemical decomposition of the zinc chloride.

The author then asks: What is electrolysis, and where is its seat? It is electrochemical decomposition produced at the points where the electric current passes from a fluid compound conductor to a solid compound-conducting body, and its seat is the contact surface.

This transfer of energy is accompanied by an unloosening of chemical affinities, and while one constituent of the electrolyte is liberated, the other is potentially freed. This potentially free constituent sets up through the body of the whole electrolyte a condition of chemical stress or stress of chemical affinity, which is transmitted from molecule to molecule to the other electrode, where the complimentary constituent is potentially free. This chemical stress, exhausting itself in diffusion effects, and the primary cause of the migration phenomena, is chemical in its nature and not electrical, and is *caused* by the transfer of the electrical energy at the surface of the electrodes. The migration phenomena are, in this view, secondary chemical effects of the transfer of the current energy at the surface of the electrodes, and are not, in any way, phenomena inseparably connected with the mechanism of the transfer of electric current through the body of the electrolyte. While electrochemical action is produced directly by the current at the surface of the electrodes, the means of communication between the two electrodes by which the continuance of that action is preserved is in no sense by means of convection currents of charged ions, but is by means of chemical stress transmitted entirely independently of the mechanism of the conduction of the current through the body of the electrolyte.

The paper elicited a long discussion, in which Messrs. Hering, Roeber, Patten, Bancroft and Kahlenberg participated, all of which pointed out that the one experiment, quoted by Dr. Richards, in support of his theory, could not be considered a sufficient proof; the current used is so small and the time so short that one would not be able to detect the products of electrolytic decomposition; while the other observations made by the author present nothing unusual. Dr. Kahlenberg remarked that similar views have formerly been expressed by others; thus, Mr. C. J. Reed has expressed the belief that if, instead of removing a metal from a solution by electrolytic deposition, one would remove the metal by some other means from the solution, the concentration changes resulting in the interior of the electrolyte would be the same.

Electrolysis of Fused Salts.

A paper by Prof. R. Lorenz, of the Institute of Technology of Zurich, was then presented on this subject. In the absence of the author it was read in abstract by Dr. E. F. Roeber.

The author makes some introductory general remarks on the difficulties in the preparation of the electrolyte, and on the difficulties of devicing a suitable vessel. For instance, for the electrolysis of fused zinc chloride, a porcelain vessel would be absolutely unsuitable; there would be no normal electrolysis. An apparatus of wide applicability is the wrought-iron V-formed electrolyzer of Helfenstein. (Fig. 6.) The reasons for the construction in V form will be given later. The main requirements for any apparatus of this kind are: It should be easy to handle and it should be possible to maintain the temperature constant. The V-formed electrolyzer is good for all work in the laboratory. For temperatures up to about 700° C. refractory glass is used, beyond that temperature porcelain.

The author then discusses at length some peculiar phenomena which are characteristic for the electrolysis of fused salts. It is an exception if, without special precautions, the electrolysis is normal, *i. e.*, in accordance to Faraday's law. To point out the disturbing elements in the electrolysis of fused salts, the author gives two examples.

First, electrolysis of lead chloride. Faraday himself showed that his law is fulfilled in this case; but he could prove this only by using a molten lead cathode. If a V-tube is used, with carbon electrodes, and a temperature of 600° to 700° C., the cathodic compartment soon assumes a dark color, while the anodic compartment is yellow and clear. There appears a very important phenomenon, the formation of metallic mist in the salt near the cathode. This may be either a real solution of the metal in its fused salt, or a mechanical suspension of the metal in finely powdered form. This phenomenon depends to a considerable extent on the temperature and vapor tension. From experiments made by Lorenz and Auerbach it seems possible that we have here in fact a real solution of the metal in the fused salt. A reguline deposition of the metal at the cathode takes place only when the fused salt is nearly saturated at the cathode with the metallic mist.

When the metallic mist comes in contact with the anode, it acts as a depolarizer and prevents the development of chlorine; the original salt is then simply reformed or regenerated.

FIG. 6.—APPARATUS FOR ELECTROLYZING FUSED SALTS.

With small current densities this phenomenon may become so prominent that the salt conducts the electrical current apparently like a metal does.

The second example discussed by Lorenz is electrolysis of zinc chloride. There we have not only the troubles due to formation of mist, but troubles due to basicity. There are two kinds of commercial zinc chloride. One kind is suitable for electrolysis; the other is not. The trouble is due to the content of water. A content of even less than 0.78 per cent of water is detrimental. Lorenz and Gruenauer removed the water from the molten zinc chloride by means of hydrochloric acid gas; if certain conditions are maintained, one gets $ZnCl_2$ in a condition in which it may be easily electrolyzed.

The author then dealt with Faraday's law in the electrolysis of fused salts. The formation and the movements of the metal mist through the bath cause the deposit to be less than fallows from Faraday's law. The ampere-hour efficiency is the higher the better the action of the mist is prevented—this may be more or less accomplished by removing the two electrodes from each other, by making the apparatus of such cross-section that diffusion is prevented—by using a high-current density—by using a relatively low temperature.

The main point would be to prevent completely the formation of the metallic mist. Lorenz and Appelberg have found that there are in reality substances which, when added to the bath, prevent the formation of the mist entirely. The author thinks this is an important point for industrial applications, for instance, manufacture of aluminium. Secondly, if mist is formed we must try to prevent its diffusion. This is done by the V-tube. By carefully enclosing the electrodes, we can get an ampere-hour efficiency of nearly 100 per cent. The only disadvantage of this apparatus is its high resistance.

Now, if a certain apparatus is used, and if the temperature is maintained constant, then if we vary the current, the ampere-hour efficiency decreases with decreasing current and it becomes zero, before the current itself is zero. There is the empirical relation $\text{efficiency} = 100 - \frac{k}{i^n}$, where i the current and k and n constant figures depending on the construction of the apparatus and the temperature. This formular is very exactly fulfilled.

In the beginning of the electrolysis, the ampere-hour efficiency of the anodic reaction is not the same as that of the cathodic reaction, but they become equal if the electrolysis is continued for a sufficient length of time. In the beginning, less chlorine is developed; this is because the carbon anode is being saturated with chlorine.

The author then discussed the phenomena of counter e. m.

f. and polarization. The polarization also depends on the mist formation. As soon as the mist reaches the anode, it acts as a depolarizer. For lead chloride at 600° C., the normal polarization e. m. f. is 1.2 volts. If the metal mist, however, reaches the anode, the e. m. f. decreases at once to 0.6 or 0.8 volt. As soon as the mist is again cut off from the anode, the e. m. f. rises again to its normal value. This is shown in Fig. 7. There is a complete parallelism between the phenomena of ampere-hour efficiency and polarization.

Caustic soda shows two values of polarization, one 2.14 to 2.19, the other 1.3 to 1.1. One point corresponds to metallic sodium at the cathode against oxygen at the anode. The other point corresponds to hydrogen at the cathode against

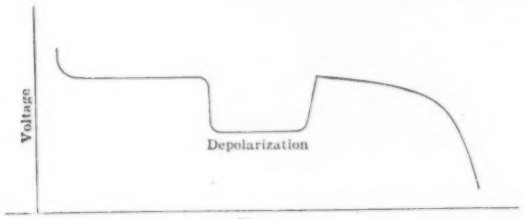


FIG. 7.—DEPOLARIZATION CAUSED BY CONTACT OF THE METALLIC MIST WITH THE ANODE.

oxygen at the anode. The author finally showed that the Gibbs-Helmholtz rule is fulfilled, and gave some theoretical considerations. The paper was not discussed.

Electrolysis and Catalysis.

The last paper of the session was that of Prof. Wilhelm Ostwald, of the University of Leipzig, Germany. In the absence of the author, it was read and briefly discussed by Prof. W. D. Bancroft, who illustrated Ostwald's views by some examples. The paper is published in full on another page of this issue. There was no further discussion.

This completed the work of Section C of the International Electrical Congress. The members were, however, invited to attend the separate meeting held on Friday by the American Electrochemical Society.

Friday Session.

The Friday session was an independent meeting of the American Electrochemical Society, designated as a joint meeting with the (German) Bunsen Society and the (British) Faraday Society.

At the opening of the session, Dr. Hans Goldschmidt, of Essen-Ruhr, Germany, presented to the meeting the good wishes of the Bunsen Society in a felicitous little speech. He referred to the fact that the Bunsen Society and the Faraday Society have both selected their names from one of the most distinguished electrochemical scientists of their countries. Both Faraday and Bunsen had one peculiarity in common in all their researches. They placed the experiment and experimental evidence above everything. Faraday, while deeply religious and even inclined to mysticism, was most skeptical with respect to experimental evidence—especially if the experiments had been made by others. Dr. Goldschmidt then told an incident from his university life when he studied with Bunsen; he once proposed to Bunsen a simple modification of an analytical method which had given him correct results in five cases; but Bunsen called his attention to various details which might prove disturbing elements and suggested to him to come back with his simplified method when it would have given exact results in fifty cases under most careful consideration of all details. As a matter of fact, Dr. Goldschmidt said he did not come back to Bunsen with his method since scrutinous tests showed its weak points.

Dr. Goldschmidt then argued that both the Bunsen Society and the Faraday Society, by selecting their names, had indicated the spirit in which their members intend to work. Too often, Americans consider European electrochemists, especially those from Germany, as mere theorists (Denker and Dichter). However, the earnest endeavor to place experimental evidence above everything should be a strong connecting link between the two European electrochemical societies and the American Electrochemical Society, the work of which tends to achievements on a large industrial scale.

Prof. J. W. Richards, as a member of the Faraday Society, extended the good wishes of this society to the meeting, and expressed the regrets of several British electrochemists, who had intended to attend the meeting, but were detained in the last minute.

An Analytical Study on the Deposition of Aluminium From Ethyl Bromide Solutions.

A paper on this subject was presented by Dr. H. E. Patten, of the University of Wisconsin. The main results of the author's experimental investigation are as follows. Plotnikoff's values for the conductivity of aluminium bromide dissolved in ethyl bromide were found to be reliable; and his deposition of crystalline aluminium from such a solution was confirmed by the author. Crystals of aluminium bromide near 0.5 cm. on edge were formed from the fused salt; they belong to the rhombohedral division of the hexagonal system and resemble calcite. The purified aluminium bromide is not white, but very light yellow. Decomposition curves for dilute and concentrated solutions of aluminium bromide in ethyl bromide were determined by the author with platinized, and with polished platinum electrodes, as well as with aluminium electrodes. Aluminium has a single potential of + 1.10 volt against a 40.95 per cent solution (by weight) of aluminium bromide in ethyl bromide; and bromine, a single potential of — 1.20 volt.

A current density of 0.0023 ampere per square cm., or about 2 amperes per square foot, is just sufficient to compensate for the solvent action of the solution upon the deposited aluminium in a concentrated solution (40.95 per cent). A dilute solution (4.38 per cent) failed to yield aluminium even at moderately high-current density. An aluminium anode, which has been stripped of its film electrolytically, gave 2.235 volts in a 4.38 per cent solution of $AlBr_3$ in ethyl bromide against a platinum cathode. Similarly magnesium gave 2.227 volts, from which, by subtracting — 1.20 for bromine, we get + 1.08 volt as the approximate single potential of magnesium against this solution. A striking exception to the Nernst-Thomson rule is cited by the author in that ethyl bromide with a dielectric constant of 8.9 yields a solution of good conductivity with aluminium bromide as solute.

The investigation of the author has a bearing upon the phenomena of the aluminium anode. A film appears to be formed upon aluminium in a solution very free from oxygen; it can be removed by using the aluminium as cathode, but the higher counter e. m. f. mentioned by former investigators has not been found thus far by the author. Finally, though the results as to the electrolytic deposition of aluminium are theoretically very interesting, the author concludes that aluminium bromide, dissolved in ethyl bromide, lacks the requirements of a commercial plating solution for the deposition of aluminium.

In the discussion which followed, Prof. W. D. Bancroft spoke of the uncertainty of Ostwald's zero of potential used by the author; this is rather a matter of assumption or agreement, since we have no reliable method at present of measuring single potential differences. Prof. J. W. Richards expressed his interest in the paper on account of the use of a non-oxygen containing electrolyte for the deposition of aluminium.

Aluminium Rectifier.

A paper on this subject was presented by Prof. Wilder D. Bancroft, of Cornell University. In the experiments seamless aluminium tubes bent in U-form were employed. They

were water-cooled. The other electrode was lead. Phosphoric acid was used as electrolyte.

When the current is gradually increased, the current efficiency starts very low about 50 per cent, and is later on pretty nearly constant, about 75 or 80 per cent. The power factor starts with 35 per cent and goes up to 90 per cent with increasing current. The watt-hour efficiency is low, starting with about 50 per cent and going down to 30 per cent. The author endeavored to explain some of these observations, although he said that the matter is not yet entirely cleared up. With ammonium phosphate solutions he had been told that much higher energy efficiencies can be obtained, but he does not yet see the reason for it. The paper is only a preliminary one and the author's investigations are to be continued.

In the discussion Prof. C. H. Burgess referred to his and C. Hambuechen's paper (Transactions American Electrochemical Society, Vol. I., page 147) in which he had endeavored to give a complete analysis of the losses in the aluminium rectifier. He referred to his view of electrolytic valves, consisting of openings in the protective coating which expand and contract according to the direction of the flow of current. Prof. Bancroft thought that this view of the valves had been exploded by more recent investigations made in England. Prof. Burgess replied that he still believed in his theory and referred to the photographic evidence of the condition of the surface of the aluminium electrode. Prof. Bancroft replied that this experimental evidence exists, but it is a different thing what to conclude from it; Burgess considers the whole current to pass through the perforations in the film, while Bancroft considers the perforations as a source of inefficiency of the film, the whole film being active.

Some Aspects of Applied Electrochemistry.

A paper on this subject was presented by Mr. Woolsey McA. Johnson, of La Harpe, Kas. The author makes the introductory remark that perhaps the title of his paper would be more appropriate were it given as Commercial Aspects of Electrochemistry. It is not crass and materialistic to look first upon any applied science purely in its industrial aspect. A metallurgical process should first of all make money for those who have put their capital in the enterprise. The late Prof. Eggleston, of the Columbia School of Mines, defined metallurgy as the art of making money out of ores. Thus, it is with any electrochemical proposition that the test of any process is its commercial efficiency. A process that does not fall in this category is as sad a sight as an abandoned New England farm. It has come into an existence for which it was never intended. A deserted smelter connotes to one's mind a feeling of sadness for the misplaced and misdirected energy, whereas, on the other hand, a well-managed and efficient plant like the Homestead Works of the Carnegie Steel Company, or one of the large electrolytic copper refineries has something grand and lofty about it like a play of Shakespeare's or an opera of Wagner's. Viewed in its widest relations, practical science is not only compatible with the use of the imagination, but for the greatest development in this line the highest imaginative and creative powers are necessary.

Mr. Johnson remarked that there are certain principles of economics and certain principles of applied science which hold good for any branch of practical work. A metallurgist combines different agents and different forms of apparatus to produce his desired effect. To wit: Large production with high recovery of values and a pure product. He is also under the stress to do this commercially. Thus, it will be seen that the laws which govern metallurgical operations are really when viewed in perspective, the combination of certain scientific and economic truths. It may be said that applied science amalgamates two studies, economics and natural science.

One of the first things in starting up any new proposition that is to compete with an old and established process is that it is of prime importance to know the defects and good points of the old business. The question of the cost of raw material, the cost of treatment per ton of raw material, the usual losses, the purity of the product which is demanded by the present market should be known with exactness. Such a knowledge will show the weak points of the old metallurgy and many a football game has been won by hammering at a weak tackle. As has been said, the new proposition should make an attack on the weakest point. For instance, much has been published in the past two years about the so-called developments in the electrometallurgy of iron and steel. By a sort of natural evolution it has been seen that the processes which have been selected as survival of the numerous attempts have cast on the weakest spot in the present metallurgy of steel. In the manufacture of crucible cast steel the cost of fuel, cost of crucibles and high labor charge per ton of output makes an expensive product. This expensive product binds the market solely and simply because of its purity, which fills special uses. With crucible cast steel quality is the desideratum. It is self-evident from the nature of electric heating that large units, durable furnaces, low charge of labor per ton of product, ease of control over the purity of the product, that the fact comes out in bold and prominent relief that here is the first chance for a marked victory of the electrical method over the old style of metallurgy.

The second point which should be brought out is that not only should the present status of the old process be known but also a keen forecast should be made as to what improvements the old process is susceptible of. Mr. Johnson referred to an article in our last issue on the manufacture of sulphuric acid by the contact process. There the anonymous writer showed that under the stimulus of competition from the new contact process, the old process has been improved greatly, as regards consumption of nitre and pounds of acid made per cubic foot of chamber space. A meek and timid man will make a good fight if pushed to a corner. So capital will spend thousands of dollars in making changes in plant and process, if it is seen that the life of the company is threatened. Where suggestions as to improvements from the technical force were thought by the head office, to say the least, in distinctly bad taste, in times of complacent prosperity, it is soon seen in the period of war that new ideas and reforms are quite welcome.

Mr. Johnson emphasized that any new process should have a good margin over any possible future cost of production of the old process. The most successful nations have "a preference as a race for fighting ten to one." So, too, with applied electrochemistry, the battle should be fought along the line of least resistance.

It is a truism to remark that any electrochemical process is doubly strong if it combines the best part of the old metallurgy with something new of its own. A principle of practical metallurgy is that for producing the desired results, two, three, or even many more treatments are made to attain the end results. For instance, in the treatment of copper ores in Montana we have first, very cheap mechanical concentration by water, next smelting in regenerative reverbatory furnaces or the roaster blast furnace treatment to a 50 per cent matte. Next, mesmerizing in the copper converter to blister copper, then refining in the reverbatory refining furnace to set copper, and finally electrolytic refining.

Mr. Johnson classes these metallurgical reactions as roughing reactions, intermediate reactions and finishing reactions, the meaning of the terms being self-evident.

The reason for the fact that we have several reactions quite often is that a reaction will work very cheaply, and without undue loss, if it be not pushed to too far an extreme. It then becomes expensive in operation. Now, for the finishing reaction, for the last part of the work, a more expensive reaction can be used which gives low losses and the pure products. Examples of this principle are seen in every metallurgical works. For instance, in its simplest and boldest form in unloading coal or ore from a barge, 90 to 95 per cent can be removed by

mechanical means. The last five or ten per cent must be unloaded partly by man and wheel-barrow. Again, in the copper work it is not practical to make in the matting process a matte running over 50 per cent, for, with a 60 per cent matte the slags would be so high in copper that they could not be put over the dump. Again, in roasting a pure nickel matte to a dead oxide it is very cheap and easy to reduce the sulphur to half of one per cent in a mechanically operated roasting furnace. It is then good practice to use a special roast in hand reverbatories to bring the sulphur to 0.02 per cent. The last operation is expensive, and would prohibit the process if it were attempted to remove all of the 400 pounds of sulphur in the matte by its means. But it is cheap and efficient for the last ten pounds remaining after the first treatment. The principle can be stated that usually a combination of reactions, each suited for its own duty produces the cheapest metal. This general principle is one which has been, and should always be, applied in an electrochemical proposition. For instance, in the electrolytic refining of copper the electrolytic treatment is the last and finishing reaction. Many attempts have been made to use anodes of matte or ore, but only failure has been met with in these attempts. The anode has always been purer after each failure. Now at the present time the practice is to use an anode of refined copper where silver is the chief purity. In this connection it might be noted that the very low percentages of arsenic and antimony present in blister copper could not be removed in anything like the efficient manner as they are done in the electrolytic treatment. History shows that in electrolytic copper refining the cheapest method has been found to use the prior methods for the roughing reactions, and to put on the finishing touches of the refining in the electrolytic bath.

Mr. Johnson then considered any possible future developments in the electrical treatment of nickel material. The alkaline sulphide treatment is very cheap in making a nickel matte containing about one per cent of copper. To remove the last one per cent of copper by this method is done at a great expense. Just here it is possible to apply an electrical method and cheapen the process. In all probability future developments in the metallurgy of nickel will be along these lines.

Another consideration brought forward by Mr. Johnson, is that it is often good business to push a plant to its maximum capacity with high losses, but with an increased output. For instance, in the zinc business, it might be possible to make a charge of roasted ore and reducing material of such a nature that the losses in smelting are very low. But the result of the improved smelting is soon seen on the cost sheet in the increased cost of producing spelter. The old golden mean must be aimed at, and the charge should be made, not for the satisfaction of the metallurgist, but for the purpose of making cheap metal.

In a case where the electrochemical proposition enters a radically new field, conditions are much changed. New products like carborundum or graphite mean that a market must be worked up by skillful advertising along lines which show that their possibilities are great. The author concludes that the modern view of esthetics is that the test of any object is its efficiency. A thing is considered beautiful by the human mind because it connotes in the human mind the sense of efficiency; by efficiency being meant ability to do its duty well. We have in the vista of the brain a dim idea of this efficiency. So, too, with a metallurgical process. A beautiful process is one that does its work well and cheaply.

Testing the Temperature in Electric Furnaces.

A paper on this subject was presented by Mr. Francis A. J. FitzGerald, of Niagara Falls, N. Y. In the absence of the author it was read by Dr. J. W. Richards. The author points out that amorphous carbon, when heated to high temperatures, undergoes various physical and chemical changes. The most important ones are increased density, increased heat conductivity, decreased electric resistivity, increased resistance to oxidation when heated in oxygen, and increased resistance to the disintegrating action of certain solutions.

Mr. FitzGerald points out that by observing the changes which a piece of carbon has undergone while it was subjected to a high temperature, it is possible to estimate this temperature. This is especially useful for studying the temperatures at various points within an electric furnace. The one change which is best suited for such tests is the change in density, and it is this which Mr. FitzGerald proposes to utilize. With very high temperatures amorphous carbon changes to graphite, but even after the change of all amorphous carbon into graphite, there is still an increase in density. A table of densities may therefore be prepared which at the same time indicates the temperatures to which the sample of carbon was heated. The author points out, however, that the density is not simply a function of the temperature alone, but also of the time of heating and of the kind of carbon used.

He then describes the following experiments. A mixture of powdered petroleum coke and pitch was moulded in the form of a rod and baked at a dull red heat for about ten hours. The rod was then broken up and specimens were heated to various temperatures. The densities of the specimens were determined by means of a specific gravity bottle, alcohol being used as the liquid in the bottle, since it wets carbon much more readily than water. A pump was used for removing the air from the pores of the carbon. A series of determinations were made to get a measure of the accuracy of the density determinations, with the result that the percentage average deviation was found to be 0.044. The results are given below, where the densities are those of the carbon at 20° C., compared with water of 4° C.

Specimen.	Temperature.	Density.
1.	Dull redness	1.9141
2.	Above melting point of $CaCl_2$, Below that of Ag.	1.9612
3.	Above melting point of Ag.	1.9853
4.	Above melting point of Cu, below that of cast iron	2.0061
5.	Above melting point of cast iron	2.0363
6.	Heated in platinum crucible over blast-lamp	2.0585

The author gives some results of the application of this method to the study of temperatures in an experimental furnace. The experiments were made by Mr. FitzGerald in conjunction with Mr. P. McN. Bennie. A greater number of samples of carbon were placed at different points in the center and at the ends of a muffle furnace, and it was thus detected that there was a great difference in the temperature in the center and at the ends on account of insufficient heat insulation; the distribution of temperature throughout the furnace was influenced by defective heat insulation. Having detected this, it was easy to correct the design of the furnace. Care should be taken that pure amorphous carbon is used since if impurities like iron, etc., are contained they may volatilize at high temperatures, and may thus produce an apparent change in the density.

Electrolytic Separation of Cobalt and Nickel.

The last paper of the session, by Prof. Wilder D. Bancroft, of Cornell University, dealt with this subject. It was presented by the author in brief abstract only, and referred to a method which should be especially useful for the purification of cobalt, as well as of nickel salts by continual electrolysis. The method requires considerable time, but if time is no object, it yields pure cobalt salt or pure nickel salt.

On motion of Prof. C. F. Burgess a vote of thanks was extended to the organization committee of the International Electrical Congress. Prof. Henry S. Carhart referred to the high quality of the papers which had been presented at the different meetings. Then the meeting adjourned.

Papers on Electrochemical and Allied Subjects Before Other Sections of the Congress.

In the following we give notes on papers on electrochemical and allied subjects, presented in other sections of the Congress. The fact that there were such papers is an interesting indication of the steadily increasing influence of electrochemical methods in the other branches of electrical engineering.

Section A.

In Section A three papers were presented on units. Prof. M. Ascoli advocated the "rational" system of Giorgi, by which the factor 4π is eliminated from various formulas, while the present accepted "practical" units are not affected. A paper on the absolute value of the e. m. f. of the Clark cell was contributed by Prof. H. S. Carhart and Prof. G. W. Patterson, Jr.; the results thus far obtained show the e. m. f. at 15° C., to be nearer 1.433 than 1.434. In a paper on "the so-called international electrical units," Dr. F. A. Wolff recommends some action to be taken which will bring about greater uniformity in the units adopted in the various countries. There was an animated discussion in which American and foreign scientists equally participated, the tendency being in general toward conservatism.

Several papers were presented on applications of the electron theory. Prof. C. D. Child gave an explanation of the phenomena of the electric arc on the basis of the electron theory. Prof. J. J. Thomson communicated a paper on "the corpuscular theory," the main part being the experimental proof that the ratio of weight to mass is the same for radium as for other substances. Prof. A. G. Webster contributed a "report on recent developments in electrical theory," dealing with Lorentz's electron theory. Prof. E. Rutherford gave an account of his continued researches on the transition stages of radium. Prof. P. Drude presented a paper on electric conduction in metals, from the standpoint of the electronic theory, Prof. J. S. Townsend a paper on the theory of inization by collision in gases, and Prof. P. Lewis on the electrical conductivity of gases. The latter emphasized that while ions undoubtedly conduct the current through gases, there are very marked differences from the much better understood phenomena in electrolytes. Dr. K. E. Guthe applied the theory of electrons to coberer action.

Prof. H. T. Barnes presented a paper on the mechanical equivalent of heat measured by electrical means. He concludes that the most probable value of the mechanical equlvalent of heat, electrically measured, is 4.186 joules in terms of the mean thermal unit which is a mean over the range from 0° to 100° C., and thus independent of any temperature scale.

Section B.

Electrolytic Rectifiers.

A paper on this subject by M. Albert Nodon, of Paris, was read in abstract by Dr. C. P. Steinmetz. The author defines an electrolytic valve as a device, which is able to interrupt the flow of an electric current when it is in one direction, and to permit its free passage when in the other direction. "It consists essentially of a metallic anode of small surface, a cathode of large surface and an electrolyte, which last is generally a salt solution." * * * "The value of the electric charge that may be obtained by means of the valve effect is greater as the molecular weight of the metal which constitutes the anode is smaller. Magnesium and aluminium admit of the valve effect being obtained under a high difference of potential; metals of large atomic weight, such as lead or mercury, on the other hand, produce the valve effect only under a low difference of potential."

"The valve effect may be obtained with ordinary water. In practice, however, the choice of electrolyte is important in the operation of the valves as a result of the more or less destructive nature of the secondary products of the electrolytic reactions. With magnesium, the best results are obtained by means of a saturated solution of alkaline fluorides. With aluminium, the most perfect action is secured by means of neutral ammonium phosphate. The phosphates of potassium and sodium give rise to free potassium and sodium which attack the electrodes and produce an imperfect action of the valves."

The author gives tables showing the results obtained with various metals and electrolytes. Concerning the electrostatic capacity of the valves, he says that he has measured the electrostatic capacity of a valve whose surface had but 0.1 square mm. extent, and which was charged to a difference of potential of 2 volts during a period of less than 0.01 second. The capacity found was from 7 to 10 microfarads." For larger surfaces the capacities are not at all correspondingly larger. "For a given surface the capacity diminishes very rapidly with the time of charge, as a result of the proportional augmentation of the thickness of the film."

The author describes the arrangement and connections for using electrolytic valves for the rectification of alternating currents, and gives results of tests of the wave form.

Section D.

Aluminium for Electrical Conductors.

A paper on this subject was presented by Mr. H. W. Buck, of Niagara Falls. The legitimate uses of aluminium in electrical work are for appliances such as bus-bars, high-tension line conductors and low-tension feeders not requiring insulating covering. Whenever insulation is required, the large cross-section required for aluminium for a certain conductivity, would make the cost of the insulation prohibitive. For this reason aluminium is not suited for interior wiring. Aluminium is difficult to solder, probably since there is always a very thin film of oxide on its surface. But aluminium has now passed the experimental stage for use as conductors. The early troubles from breaking at unexpected places have been overcome in the present stranded conductor. It is durable, except when exposed to sea fog and to atmospheres filled with chemical fumes, and the wire can be given a weatherproof covering in such neighborhoods. The trouble from sleet seems to be less with aluminium than with copper conductors. It costs less to transport and string than copper because it is lighter. When stringing in rough country, however, more care is necessary than with copper to avoid abrasion of the soft aluminium conductors. Soldering aluminium joints has not been found necessary. The author gave the results of tests of the wind pressure on spans. It is proportional to the square of the velocity of the wind.

In the discussion of the paper, Mr. P. N. Nunn questioned whether in actual practice the deflection of aluminium spans under highest temperatures is more than copper, because aluminium is usually strung so that it has enough less deflection than copper in the coldest weather to make the deflection not in excess of copper at the highest temperatures. Aluminium conductors are most apt to be broken by arcs. In the five years' experience that the Telluride Power Transmission Company had with aluminium on lines in Utah and Montana, he remembered but one break not due to an arc. Mr. C. W. Hutton said that in crossing valleys the California Gas & Electric Company had been trying long spans. There was one 1,800-foot span of aluminium cable. There was no trouble from crossing of wires in the wind as all conductors would swing in unison.

Section E.

Mr. Arthur Wright communicated a paper on recent improvements in electrolytic electricity meters. Dr. C. P. Steinmetz presented a paper on the electric arc, pointing out the typical features of the mercury arc and the magnetite arc. Prof. A. Blondel communicated a report on impregnated arc lamp carbons and Mr. H. N. Potter a paper on the development and the characteristics of the Nernst lamp.

Mr. Gerhard Goettling read a paper on storage batteries as an adjunct to central station equipment, discussing the practice of the Edison Companies in the United States. He

pointed out that the battery plates, as now generally used, show great improvements over those of previous years. The positive consists of a rigid conducting support, holding in place soft lead buttons of coiled ribbon with corrugated surfaces, these buttons extending slightly beyond the surface of the grid. The negative plate now consists of a hard metal supporting grid in which the various sections of active material are securely held in place by means of a thin covering of perforated sheet lead. An important development is the substitution of thin wooden diaphragms between the plates as separators in place of the glass tubes heretofore generally used. This new separator effectively prevents any possibility of short circuits forming between the plates, thus keeping the cells in uniform condition, and resulting in a very considerable increase in the life of the plates.

In the discussion of this paper Col. Crompton remarked that the life of a battery is limited by the life of the end cells: for this reason he considers regulation by means of a reversible booster to be preferable to the use of end-cell switches. Mr. J. W. Lieb emphasized that with the present system of generating and transmitting alternating currents to converter substations, storage batteries are absolutely necessary in the latter in order to insure continuous service under all conditions.

SECTION F.

Mr. J. B. Entz, of Philadelphia, Pa., presented a paper on the application of storage batteries to railway service. He stated that by the use of batteries in railway power stations savings, amounting in cases to 15 or 20 per cent, may be obtained. The positive plates should be of the Planté type, and the negative of the Faure pasted type.

SECTION H.

Besides various papers in which attempts were made to apply the principles of electrochemistry and physical chemistry to biology and medicine, a paper was presented by Prof. J. W. Langley on the electrolytic purification of drinking water with aluminium electrodes. In a plant in Cleveland, Ohio, the electrolyzer is a rectangular iron box, containing aluminium plates held in grooves in a slate lining, where 500 gallons of lake water per hour are purified, the electric power consumed being 300 watts. Chemical analysis shows the albumenoid ammonia to be reduced upward of 75 per cent and the bacteria from 97 to 99 per cent. In no instant in six months of continuous commercial operation has a single colon bacillus been found, though the lake water generally contains them.

In the following we give an alphabetical list of those who enrolled their names in the register of the American Electrochemical Society: W. D. Bancroft, Ithaca, N. Y.; H. T. Barnes, Montreal, Canada; O. W. Brown, Bloomington, Ind.; William Hand Browne, Richmond Hill, N. Y.; C. F. Burgess, Madison, Wis.; H. S. Carhart, Ann Arbor, Mich.; C. D. Chasteney, Rutherford, N. Y.; H. B. Coho, New York City; F. E. Drake, St. Louis, Mo.; L. H. Flanders, Pittsburg, Pa.; R. E. Fowler; C. Hambuechen, Madison, Wis.; W. J. Hammer, New York City; W. D. Harris, Philadelphia, Pa.; Carl Hering, Philadelphia, Pa.; P. L. T. Héroult, La Praz, France; G. G. Hitchcock; B. H. Hite, Morgantown, W. Va.; G. M. Howard, Philadelphia, Pa.; E. J. Hutchinson, Cincinnati, Ohio; W. McA. Johnson, La Harpe, Kan.; Louis Kahlenberg Madison, Wis.; E. F. Kern, Lansingburg, N. Y.; M. G. Lloyd, Washington, D. C.; H. T. Matthew, New York City; J. T. McNair; C. H. Moritz, Niagara Falls, N. Y.; H. E. Patten, Madison, Wis.; W. G. Patterson, Ann Arbor, Mich.; W. M. Petty, Rutherford, N. J.; A. Pinkerton, Vandergrift, Pa.; Cecil P. Poole, New York City; J. W. Richards, Bethlehem, Pa.; E. F. Roeber, New York City; G. A. Roush; S. S. Sadtler, Philadelphia, Pa.; S. Sheldon, Brooklyn, N. Y.; C. P. Steinmetz, Schenectady, N. Y.; S. Tada; E. R. Taylor, Penn Yan, N. Y.; L. A. Terven, Pittsburg, Pa.; F. J. Tone, Niagara Falls, N. Y.; E. H. Whitlock, Cleveland, Ohio; M. I. Wilbert, Philadelphia, Pa.; H. H. Willard; T. A. Witherspoon, Washington, D. C.; T. Wolcott, Brooklyn, N. Y.; F. A. Wolff, Jr.

NEW YORK MEETING OF THE SOCIETY OF CHEMICAL INDUSTRY.

The twenty-third meeting of the Society of Chemical Industry—the first held in the United States—was called to order by the president, Sir William Ramsay, in the gymnasium of Columbia University on September 8. There were present 700 or 800 persons, and the meeting was probably the most notable one ever held by chemists in the United States. Dr. C. F. Chandler welcomed the meeting on behalf of the University and the New York Section of the Society.

Besides the official business—the presentation of the reports of the secretary and treasurer—the chief feature of the meeting was Sir William Ramsay's address as retiring president, which is given in abstract below. The new president, Dr. William H. Nichols, proposed the vote of thanks to Sir William in a felicitous little speech.

A very pleasant incident was the presentation of the Society's gold medal, founded in 1886, by Sir William Ramsay to Dr. Ira Remsen, of Johns Hopkins. Dr. Remsen answered in a very modest way, saying he wished he could feel he had more fully earned the honor; as it was, if for no other purpose, the medal would serve to "deceive his family" with it.

THE TRAINING OF TECHNICAL CHEMISTS.

In opening his address Sir WILLIAM RAMSAY thanked the New York Section for the hospitable reception. "Gratitude has been defined as a sense of favors to come, and we know that we have reason to be grateful, for you are about to give us, your guests, a token of your regard; you are going to show us your magnificent country, and to demonstrate to us the enormous developments in chemical industry which you have made. We look forward with pleasurable expectancy to the treat which you have in store for us, and we ask you to accept our heartfelt thanks."

After some remarks on previous presidential addresses, Sir William Ramsay proposed to discuss himself some first principles in the training of technical chemists. The education of a chemist (and the word "chemist," of course, includes the qualification "technical chemist") must be conceived in the sense that it consists in an effort to produce an attitude of mind rather than to instill definite knowledge. Of course, the latter must not be neglected. The definite knowledge may be likened to the bricks which the architect has at his disposal in erecting a beautiful building; he knows their shapes, their capacity for resisting stresses, and, in short, what can be done with them. But the conception of the design is the result of many attempts to create; just as the poet has to utilize words, or the architect bricks, so the chemist has to know the materials with which he is dealing. The training of a bricklayer, however, will never make a man an architect; nor will the dry research of a grammarian train a poet. In short, it is the inventive faculty which must be cultivated.

Sir William replied at once to the possibile criticism that the inventive faculty must exist and cannot be implanted. He denied it and contended that most of the lads who enter a chemical laboratory are able to receive some inspiration or to have a latent inspiration developed, which will fit them to become inventive chemists.

Now, how can this be brought about? "The answer is perfectly simple: by offering them examples." Every teacher in the laboratory, from senior professor to junior assistant, must be engaged in research, and, most important of all, they must not be reticent, but willing to converse freely on their problems. It is that which creates a "chemical atmosphere." The objection may be raised that junior students are not ripe enough to make any use of such examples. True, and for that reason it is well for the juniors to spend the first year attending lectures and practical classes in rooms for the purpose, and not to let beginners enter the general laboratory. Moreover, they should be attending courses on physics and mathematics, and in the drawing office. But during the second year the initiation should begin. Even during the first

year, the seniors will talk occasionally about what occurs in the main laboratories; the publication of some discovery is sure to be discussed in the junior laboratory, just as the servants' hall discusses the doings of the drawing-room, and the criticism is sure to be somewhat keen, even though—perhaps the more so because it is—founded on insufficient information.

Sir William regards it as a mistake to provide special laboratories for different classes of students. The best instruction a student can get, he obtains in having to explain his operations to his neighbors. A little care makes it possible to assort one's students, so that a shy boy is placed next a kindly senior, and a cocky youngster who thinks he knows everything, is placed next a man who will stand no nonsense, and whose chaff and banter soon dispel the inflated ideas of his own powers which the youngster has brought from his science school. Indeed, the lesson learnt is, that the chief question is not—"What does he know?" but "What has he done?"

The speaker pointed out that there cannot be a greater mistake than to keep a glassblower on the premises. Glass blowing must be learned, since it is an all-important adjunct to the research. "I cannot imagine how any one can stand the annoyance of having to wait for hours, possibly for days, for the repair of a piece of apparatus, which would probably take fewer minutes if the owner was able to manipulate a blow-pipe. Nearly the same may be said of the mechanic's place in the laboratory. Here, however, the work is slower, and in many cases the mechanic's services may be required; but for small repairs, such as soldering, repairing, contriving stirring apparatus, electrical apparatus, etc., much may be done by the student himself without any direct teaching. I confess, however, that a mechanic is necessary, if only to see that the tools are kept in order."

SIR WILLIAM RAMSAY.

After the preliminary year, Sir William does not think it advisable for the student at once to commence research. There are the usual subjects of complex qualitative and simple quantitative analysis to be mastered, the preparation of typical organic and inorganic compounds, besides physico-chemical operations. But the time spent on these may be easily too much extended. A fairly good student should have done enough in a year and a half or two years to place him in such a position that, if necessary, he can help himself when he is face to face with an analysis which he has not made before. When an analysis is regarded as a problem, it gains greatly in interest.

"Above all, not too much teaching. The essence of scientific progress is the well-worn method, trial and failure. It is simply horrible to think of the travesty of teaching in vogue in some of our colleges, where everything is provided, and where the students add one solution to another by word of command, and record their results in special note books constructed for the purpose. What do they learn? To obey? That should have been taught in the nursery. Manipulation? Manipulation consists in constructing what is required, not in using what is given. I had rather see a youth commit the Aeneid to heart than carry out such time-wasting, soul-destroying routine operations. The first may result in a stronger memory; the second is fatal to all originality.

"It may be said that by thus leaving the students very much to themselves, much time is lost. Yes; possibly at first. But the ultimate rate of progress is very much more rapid. Unless the pupil learns to be of use to himself, he cannot possibly be of any use to others. And the training consists in finding out how to do it; not in doing it; that is easy, if one knows how."

The junior staff—the assistants, instructors and lecturers—should not be treated as teaching-machines; they should have at least one-half of their time available for research. Sir William is a firm believer in joint work done by assistants and students. But the number of assistants must necessarily be much greater than the possible vacancies in chairs; here the manufacturers should step in. A member of the junior staff who has done his duty in Sir William's sense, is invaluable if he is not too old, as a works-chemist. If the assistants are to be given leisure for research, the number must be considerable; in a fact, a double staff, in a sense, must be employed.

The speaker then passed over to the senior teachers or professors. He urged that while it is possible to lecture to as many students as the largest lecture room will hold, it is not possible to supervise the practical work of more than, say, forty or fifty students. The reason why the old laboratories of Liebig, of Woehler, and of Bunsen are regarded with such loving memory by those who were the students of these great men is that the total number of students was small; they formed a family party, where the individual character of each was known, and where the father lived among his children, and was able to distribute correction, reproof and instruction in righteousness.

If the reputation of the professor is such that students crowd to his laboratory, Sir William's counsel is, not to build larger laboratories, but to appoint a new professor, with a separate chair, and a new laboratory. "But do not make your man of talent a mere administrator."

It is not necessary that all men of the profession should be highly remunerated; but it is necessary that some should. If they are to teach others, it is greatly to be desired that they themselves should be of the best of their kind. Hence, there should be prizes for the best, comparable in amount with what a successful lawyer, doctor or manufacturer would earn. These prizes should reach the right men. Concerning the method of appointment to chairs he recommends the selection by a committee in which the vacancy occurs, after a reasoned report in which the relative merits of all the possible candidates are discussed. "One is much more particular when one has to choose a fellow teacher with whom one has to pass one's days. It is like choosing a wife. A lady chosen by the vote of the families may prove a success, and no doubt often does. If the wife were chosen in cool blood by the man who is to live with her, after careful inquiry into her antecedents, hereditary and otherwise, her temper, her suitability for the duties which a wife is supposed to perform, there would be fewer unsuccessful marriages. The analogy breaks down; for, unless it is a case of marrying a widow, previous experience should not be a possible consideration. But in selecting to a chair it must."

Sir William then spoke of examinations. "The older I get, the less I believe in University degrees as a test of capacity. Perhaps the reason is the manner in which degrees are awarded in England. The degree follows on one, or at most, two examinations, often by men who know the candidate only as a number, and whose idea of examination often is to set questions to trip the candidate, and not to draw out what he

can do." Sir William emphasizes that a student working under the eye of the professor and of his assistants undergoes a daily examination. He may not earn marks, but none the less, he impresses his teachers with some conception of his character, and the impression is made rather by what he can do than by what he knows.

Under present circumstances, however, as scholarships exist, and must be awarded by examination, it requires considerable ingenuity to devise a method of examination to pick out men who will make a good use of them. "I recently gave as a question for my students, 'Describe shortly the researches which have been going on in this laboratory during the past six months;' and I found the result very satisfactory. The question put a premium on the interest which a student should take in his friend's work, on the intelligence in following it, on his powers of description, and on his suggestiveness where invention had to stand for want of accurate knowledge. The after-effect of such a question, too, will be considerable. The students will endeavor in future to follow the researches of their neighbors with more understanding than they have done."

Concerning lectures, he thinks that students are much overlectured. The object of lectures is more to open out a subject, and to direct a student what to read, than to give definite information. And for that reason I think the senior teacher is the best for junior students.

Sir William thinks that it would be futile to extend courses of lectures to more purely technical subjects. The ideal plan for technical chemists would be some system analogous to apprenticeship of engineers, after they have been educated in the science, that is after the habit of mind has been largely formed.

"I have wondered if it might be possible to establish a training school for technical chemists somewhat on the following lines: To start an association having for its object the encouragement of invention, each member of which would subscribe a certain sum for the erection of buildings and plant. There would need to be a number of isolated buildings, and a considerable collection of stock plant of a small scale—stills, tanks, evaporating pans, filter-presses, vacuum-filters, centrifugal machines, crystallizing vats, and so on. The work shoud be furnished with steam and electric current. Such a syndicate might let it be known that they were willing to make arrangements with inventors, or with syndicates which had secured the patents of an invention, or secured an option on such patents."

However, he thinks that such a scheme would be only an imperfect imitation of the magnificent schools of technical chemistry which form a part of every large German chemical works. Sir William concluded the address with the following words: "It is the scientific curiosity of to-day that often becomes the trade necessity of to-morrow. A scientific friend of mine once drew my attention to the fact that most of the changes which have been introduced in industry have had their origin in the universities. Why? Because the investigator is unfettered. If a man sets himself to improve an existing process, he very likely may succeed, but he will not effect a revolution in manufacture. The purely scientific investigator who is free to follow indications of no apparent commercial import has not infrequently made discoveries of a radical nature, which have entirely changed some particular industry. I do not recommend the one to the exclusion of the other; both are best; and both are best attained by an intimate association between the universities and the chemical works. The investigator often learns much by the study of industrial processes. The chemical manufacturer who is keenly alive to his own interest will not fail to keep himself in touch with every discovery, however little it appears to be connected with his own industry."

* * * *

A report of the proceedings during the days in which the members of the Society of Chemical Industry in New York, as well as of the round trip through the country, will be found on another page of this issue.

CHAMBER OF DELEGATES, INTERNATIONAL ELECTRICAL CONGRESS, ST. LOUIS, 1904.

The Chamber of Delegates of the International Electrical Congress of St. Louis, 1904, was organized on Monday, September 12, by the election of the following officers: President, Prof. Elihu Thomson; secretary, Dr. A. E. Kennelly; assistant secretary, Dr. F. A. Wolff, Jr., of the National Bureau of Standards.

Two committees were appointed to consider specified questions. The reports of these committees, noted below, were adopted unanimously at the final meeting of the Chamber of Delegates.

The report of the committee on International Electromagnetic Units reads as follows: "It appears from papers laid before the International Electrical Congress, and from the discussion that there are considerable discrepancies between the laws relating to electric units, or their interpretations, in the various countries represented, which, in the opinion of the Chamber, require consideration with a view to securing practical uniformity.

Other questions bearing on nomenclature and the determination of units and standards have also been raised, on which, in the opinion of the Chamber, it is desirable to have international agreement.

The Chamber of Delegates considers that these and similar questions could best be dealth with by an International Commission representing the governments concerned. Such a Commission might in the first instance be appointed by those countries in which legislation on electric units has been adopted, and consist of (say) two members from each country.

Provision should be made for securing the adhesion of other countries prepared to adopt the conclusion of the Commission.

The Chamber of Delegates approves such a plan and requests its members to bring this report before their respective governments.

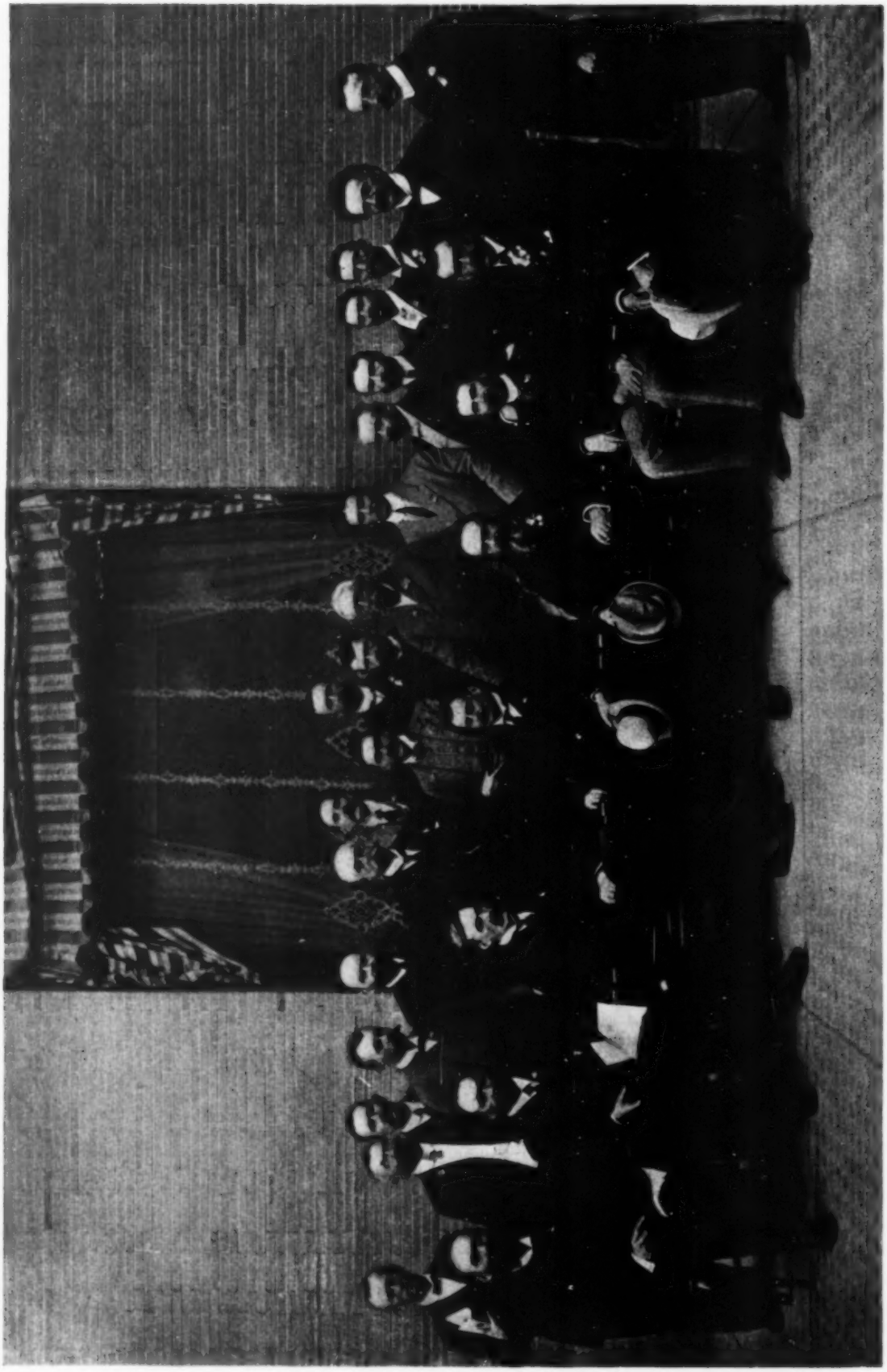
It is hoped that if the recommendation of the Chamber of Delegates be adopted by the governments represented, the Commission may eventually become a permanent one.

That the delegates report the resolution of the Chamber as to electrical units to their respective governments, and that they be invited to communicate with Dr. S. W. Stratton (Bureau of Standards, Washington, D. C.), and Dr. R. T. Glazebrook (National Physical Laboratory, Bushby House, Richmond, Surrey, England), as to the results of their report, or as to other questions arising out of the resolution."

The committee on International Standardization of Electrical Apparatus and Machinery, recommends "that steps should be taken to secure the co-operation of the technical societies of the world by the appointment of a representative commission to consider the question of the Standardization of the Nomenclature and Ratings of Electrical Apparatus and Machinery." Much of the work should be done by correspondence, in the first instance, a general secretary to preserve the records and to crystallize the points of disagreement. Communications are requested to Col. R. E. B. Crompton, Thriplands, Kensington Court, London, England, and to the president of the American Institute of Electrical Engineers, New York City.

The Chamber included representatives from eleven countries. The Congress was notified of appointments in addition from Austro-Hungary, Mexico and Switzerland, but the representatives from these countries did not appear at St. Louis. Of the five representatives of France, one did not report, and Prof. Henri Poincaré did not arrive until after adjournment of the Chamber.

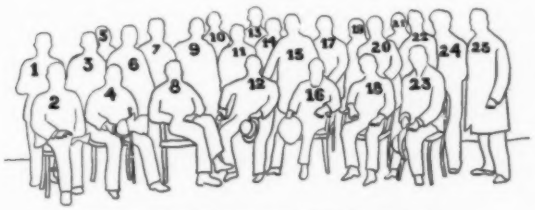
The group on the following page includes all of the delegates present at the sessions of the Chamber, except Herr Joseph



CHAMBER OF DELEGATES, ST. LOUIS INTERNATIONAL ELECTRICAL CONGRESS.
(See Key on Opposite Page.)

Vater, of Hungary. The accompanying key and following list of names will serve to identify the portraits:

1. Prof. Harris J. Ryan, United States; 2. Herr W. Litzrodt, Germany; 3. Signor A. Maffezzini, Italy; 4. Prof. Dr. Svante Arrhenius, Denmark and Sweden; 5. Dr. F. A. Wolff, Jr., assistant secretary; 6. Herr Bela Gati, Hungary; 7. M. Dennery, France; 8. Dr. R. T. Glazebrook, Great Britain; 9. Or-



KEY TO PORTRAIT ON OPPOSITE PAGE.

mond Higman, Esq., Canada; 10. Dr. A. E. Kennelly, United States, secretary; 11. Senor Miguel Otamendi, Spain; 12 Prof. Elihu Thomson, United States, president; 13. John Hasketh, Esq., Australia; 14. Capt. Ferrie, France; 15. Col. R. E. B. Crompton, C. B., Great Britain; 16. Prof. Moise Ascoli, Italy; 17. Prof. Jorge Newbery, Argentine Republic; 18. M. Zuillebot de Nerville, France; 19. Prof. L. Lombardi, Italy; 20. Marquis Luigi Solari, Italy; 21. Dr. Samuel W. Stratton, United States; 22. Prof. Henry S. Carhart, United States; 23. Senor Antonio Gonzales y Echarte, Spain; 24. Prof. John Perry, Great Britain; 25. J. C. Shields, Esq., India.

COST OF ELECTRIC POWER USED IN ELECTRIC REDUCTION WORKS.

By Louis Simpson.

The article of Dr. Louis Bell, and the paper presented by Mr. P. McN. Bennie before the American Foundry Association, both of which are printed in the August issue of the Electrochemical Industry, emphasize that the question of the possible cost of electrical energy is one of considerable importance for electrochemical works.

Both of these gentlemen admit that the question of producing steel, if not iron, has come within the range of commercial possibilities, dependent more or less upon the prime cost of electric energy. Therefore, it is of importance that such cost shall be ascertained. This can only be done by first ascertaining the cost of purchasing and developing a suitable hydraulic property, and then carefully estimating the several annual charges which go to make up the annual cost for e. h. p.

A firm intended to undertake the business of the electric smelting of iron ores, etc., would naturally seek to purchase a property which would be suitably situated for securing the necessary supplies of the raw material to be used and which would be convenient for the economical distribution of the finished product, but they would chiefly seek to secure a property where electric power could be most cheaply generated. It seems useless to consider the price now asked for e. h. p. by electric power companies. None of these companies were incorporated for the purpose of producing e. h. p. suitable for the requirements of electric ore reduction, nor are their power houses so situated as to meet the peculiar requirements of such an industry.

Dismissing, therefore, from our minds all impressions, received from the methods of electric power companies whose interests and requirements are not in common with the interests and requirements of electric ore reduction, let us examine for ourselves this most important question. The ideal location for an electric power house, the power generated being used for the purposes of electric ore reduction, must conform to the following requirements.

1. The power capable of being developed must be of considerable magnitude, not less than 20,000 e. h. p.

2. The waterfall to be harnessed should possess a head of not less than 40 feet.

3. The head should be able to be made available at a reasonable cost.

4. The conformation of the land should be such that the electric furnaces could be erected immediately adjoining the power house.

Such a location ensures the construction of a power house of considerable size, composed of large units running at medium high speeds. Such a location would in most cases eliminate the necessity for transformers and the need for expensive transmission lines.

Given such location, what would be the cost of the property, hydraulic rights and the necessary development?

Dr. Bell states that such a property would cost from $5 to $25 for each h. p. which could be developed.

Seeing that some of the land will certainly become more or less valuable for purposes other than the production of power, it would appear to be conservative enough to accept $5 per e. h. p. as a sufficient esitmate of cost. The cost of hydraulic development, outside the cost of hydraulic machinery, varies largely in every proposition, but in a favorable location should not cost more than $10 per e. h. p. Should the cost total $20 per e. h. p., the annual rental cost would not be materially increased, because, upon this extra cost, there need be no aliowance made for such charges as depreciation, insurance, maintenance or taxes. The cost of turbines, machinery and construction works, which are grouped under this heading, should not exceed $10 per e. h. p.

The cost of electric machinery up to and including the plain switch board necessary would not be more than $15 per e. h. p., unless the peculiar requirements of a process calls for very specially constructed generators.

The cost therefore will be	Per e. h. p.
Property rights, etc.	$5.00
Hydraulic development	10.00
Hydraulic machinery, etc	10.00
Electric equipment including switch board.	15.00
Total cost per e. h. p.	$40.00

Therefore, given a power house in which is generated 20,000 e. h. p., erected at a cost of $40 per e. h. p., what will be the annual cost per e. h. p., the power being used in an ore reduction works erected close to the power house, owned and worked by the same owners and under one management

The power generated is used continuously, extra furnaces being erected, so that, should one need to be shut down for repairs, another is at once placed in commission. The annual cost is made up as follows:

Wages and salaries.
Repairs and maintenance.
Taxes.
Insurance.
Depreciation.

The whole plant being constructed of metal, together with concrete, brick or stone, after the most approved modern fireproof practice, there is little or no risk from damage by fire. The repairs to buildings, etc., will be very small and the depreciation on many portions of the plant nothing.

Wages and Salaries.—The labor required per day will be that of three switch-board men, who, together with two laborers, would take charge inside the power house. On the average, three laborers per day will be required to take care of the outside work. The wages paid these eight men will not exceed, in most cases, $16 per day, or $5,840 per year, equal to 30 cents per e. h. p. There will be no salaries. The management responsible for the reduction work will be responsible for the management of the power house just as in the case of concerns using steam power.

Repairs and Maintenance.—This should not exceed 25 cents for e. h. p. year.

Taxes.—Should the property be in Canada, this charge should not exceed 5 cents per e. h. p. year.

Insurance.—A power house constructed as indicated, requires no insurance. It is advisable, however, to lay aside, to be placed to the credit of a special fund, the sum of $5,000 per year. In case of mishap or disaster the fund would be available. The annual charge per e. h. p. would be 25 cents.

Depreciation.—There is no depreciation upon the value of property purchased, nor upon the excavations made, nor upon the dredging done. Neither should the concrete work depreciate. Turbines when working under a head of water not too high, have been known to be in commission, and in a good state of repair after thirty years of work. In ordinary cases 2½ per cent upon the cost of the turbines will be found to be sufficient. Upon the electrical machinery 7½ per cent should be allowed. The charges for depreciation amount to $1.35 per e. h. p. year.

Summary.

	Per e. h. p. year.
Wages and salaries	$.30
Repairs and maintenance	.25
Taxes	.05
Insurance fund	.25
Depreciation	1.35
Total	$2.20

Were to this added interest (5 per cent) upon the cost of property and construction, the grand total would only amount to $4.20 per e. h. p. year. A calculation of cost of reduction based upon a cost of e. h. p. year at $4.50 may be claimed to be considered as conservative.

But a company owning a large electrical power plant and who intend to use the bulk of the power developed in the smelting of iron ores or in the making of steel, can in all cases find a local market for a proportion of the power generated, and this at prices highly remunerative.

Were 10 per cent of the power generated leased at $15 per e. h. p. year off the switch board, the cost of the power used in the reduction furnaces would be as follows:

100 e. h. p. at $4.20 = $420.
less 10 e. h. p. leased at $15 = $150.
Cost of 90 e. h. p. = $270 or $3.00 per e. h. p.
Were 20 per cent so leased the cost would be
100 e. h. p. at $4.20 = $420,
less 20 e. h. p. at $15 = $300.
Cost of 80 e. h. p. = $120 or $1.50 per e. h. p.

Were 28 per cent of the power generated leased at $15, the annual cost of the remaining 72 per cent would be nothing. Such a result is quite within the bounds of possibility. It will doubtless be contended that e. h. p. has never been generated at $4.50 per year. Such a contention, although perhaps natural, cannot be claimed as being worthy of consideration. "Conditions alter cases." E. h. p. has never yet been developed under the special conditions indicated. Not because those special conditions are not existent or cannot be arranged for, but because industrial conditions have hitherto been such that the special conditions which would permit of the construction of e. h. p. at these low rates have been ignored or have had to give way before the interest of other special industrial conditions. In fact electric power has been generated to meet the requirements of municipal lighting and traction, and of the users of motors rather than the requirements of electric ore reduction. The cost, therefore, has been governed by the special requirements of such users which includes conditions that compel large unproductive (as to power generation) outlays, and also very considerable extra annual expenses.

To complicate matters, the enormous and varying cost of electric transmission has too often been included in the cost of electric power generation making to the outsider "confusion worse confounded." The manufacturer of iron or steel does not seek to secure any profit out of the generation of power. He seeks his profit in the manufacture of iron or steel. If electric power be necessary to his business he seeks to secure it at a cost as low as may be possible. This he can do by arranging (as is possible) to secure the bulk of the capital necessary, to pay for the power development, by the issue of mortgage debenture bonds—power bonds being, and with reason, considered unusually safe securities.

With the capital cost of the power plant so arranged for, the capital required to undertake the construction of an electric reduction plant is very considerably less than that required for a blast furnace plant of the same annual output.

Ottawa, Canada.

Correspondence.

SOLUBILITY OF GOLD.

To the Editor of Electrochemical Industry:

Sir—The prevailing tendency to build up or "develop" a theory by unwarranted inferences seems to me a deplorable one. The theory so "developed" is too often referred to a little later as "established," although these unwarranted inferences are its only foundation.

In this connection I wish to call attention to your editorial in the August number on the "Solubility of Gold" and to the abstract of the paper of Dr. Victor Lenher printed in the same issue. I have not yet received Dr. Lenher's complete paper, but do not believe it could materially alter the case. According to the editorial and the abstract referred to, we are entitled to develop the theory that gold is dissolved or oxidized only by "nascent" oxygen, and incidentally, of course, the theory that there is a nascent oxygen which has properties different from ordinary oxygen.

The reasoning employed in this development is as follows:

1. (This is presumably the major premise.) The experimental facts show that gold is oxidized or dissolved only by very powerful oxidizing agents.

2. (Presumably the minor premise.) Experimental facts show that oxygen is liberated ("oxidized," see literature of oxidation and reduction by O. C. Johnson, E. F. Roeber and J. W. Richards) only by very powerful oxidizing agents.

3. (Conclusion.) Therefore, it is nascent oxygen or oxygen produced simultaneously in a solution which dissolves gold.

This method of reasoning is not at all new in modern scientific research and theory building, but it seems to me a matter which is not according to either recognized principles of logic or common sense.

It seems to me that the only conclusion, or at least the most evident conclusion, from the above premises would be: therefore, reagents which are capable of liberating oxygen are also the reagents which are most likely to dissolve or oxidize gold.

The fact that certain reagents are all capable of producing two independent results, separately observable, is no proof that one result is produced by the other result when both are simultaneous. In this case in particular the evidence in the facts is strong that neither of the two results is produced by the other result; that is, that the gold is not dissolved by the liberated oxygen, and that the oxygen is not liberated by the dissolved gold. Because in all of the reactions cited it is possible to produce either of the two results alone, under circumstances which do not allow the production of the other.

It is now generally recognized by chemists that oxygen can cause the oxidation of other substances only by itself going into combination and never causes oxidation by becoming liberated. There is no known chemical equation or reaction in which an atom of oxygen is liberated, and is at the same time used in producing oxidation. One atom of oxygen may be liberated and another atom of oxygen may be

simultaneously transferred from one substance to another. But there is no evidence that the atom transferred is first liberated. Even of it were, there could not be any evidence of it. The only important inference which can be drawn from the facts, is that the two separately producible results are also simultaneously producible.

This conclusion, instead of causing surprise or being difficult to understand or requiring a theory for its explanation, seems to me the natural and logical result to be expected.

Philadelphia, Pa. C. J. Reed.

[We cannot see the connection between Mr. Reed's communication on nascent oxygen, which is very interesting in itself, and the abstract of Dr. Lenher's paper and our editorial. Both the abstract of Dr. Lenher's paper and the editorial contained simply statements of facts, no attempt being made to "develop" or "establish" a theory. Neither contained the term "nascent oxygen." Our correspondent seems to have been misled by the contents on the front cover of our August issue, where Dr. Lenher's paper was briefly characterized as "an account of an experimental investigation of the solubility of gold under the influence of nascent oxygen." At that place the term nascent oxygen was perfectly justified, since it described (not explained) in few words the facts established by Dr. Lenher, namely, that gold is readily attacked in a large number of reactions in which oxygen is produced; further, that it is necessary for the oxygen to be produced in the mixture, while ordinary oxygen gas, when conducted into sulphuric acid in which gold leaf is suspended will not cause the gold to dissolve.—Ed.]

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

By George P. Scholl, Ph. D.

Electric Furnaces and Furnace Products.

Electric Furnace.—C. G. P. De Laval, Stockholm, Sweden. Patent 768,054, August 23, 1904. Application filed May 8, 1903.

The furnace is illustrated in Fig. 1. Its principle is similar to that described in the inventor's earlier patent, 729,614, of June 2, 1903, described in Electrochemical Industry, Vol. I., page 425. Its cross-section shows a furnace chamber 1, with an outlet 3 for gases or metal vapors, a tapping-hole 10 and an inlet 4 for the introduction of the material to be treated. The flat furnace bottom 8 extends from the end wall 7 to the front wall 6, and the electrodes 2 are introduced through the side walls. Cylinders 12, in which the rotating screws 14 are placed, serve to convey the charge from the hopper 13 into the interior of the furnace. It is intended by this construction to feed the material into the furnace in such a manner that it will assume the form of a pile, with a sloping or inclined face a towards the heat focus, the thickness of which pile, in a vertical direction from the hearth, diminishes continuously and is thinnest at the edge of the hearth below the electrodes. It is also intended by means of the flared inlet to have the pile rise somewhat above the inlet, so as to interpose a mass of material between the heat focus and the upper edge of the inlet. The material is fed into the furnace at such a rate as will maintain the slope at such a distance from the heat focus that no sudden development of gases will take place in the material which would be attended by losses on account of the material being thrown about in the furnace. A layer of half-molten material is thus stated to be produced on the surface of the slope and to slowly flow down, while the volatile ingredients which are liberated will escape at the outlet 3. It is preferred to place the outlet opening in such a position in relation to the electric arc, that the volatile ingredients escape directly from the sloping surface into the outlet 3, instead of passing first through the heat focus, in order to avoid raising their temperature. Where zinc ore is the material treated, the metal vapors mixed with the gases pass out at opening 3, while the residuum and the slag are melted by the heat of the arc when in their thinnest layer on the hearth, and are withdrawn through the tapping-hole 10. By reason of the distillation of the zinc and the smelting of the residues taking place in the same furnace, the operation is continuous when the charge is continuously fed in and the slag drawn off. The furnace is intended for the treatment of comminuted materials, such as pulverized ores.

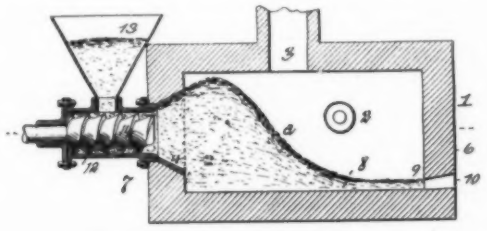


FIG. 1.—ZINC ELECTRIC FURNACE.

Electric Arc Furnace.—A. H. Imbert, Grand-Montrouge, France, Assignor to Société de Métallurgie Eléctrothermique, Paris. Patent 768,995, August 30, 1904. Application filed March 3, 1904.

The furnace consists essentially out of a rectangular chamber, which is connected at both ends with an inclined charging channel. The latter, where they abut into the furnace chamber, are just as wide as the chamber, but become gradually narrower in a vertical direction toward the charging end. The material under treatment is heated by radiation only, by means of arcs sprung between electrodes which enter the furnace through the side walls, and which are automatically advanced and cooled outside of the furnace. The furnace openings, through which the electrodes pass, are also protected by cooling tubes. Experience is said to have shown that it is necessary for the ceiling of the furnace to be as close as possible to the hearth, *i. e.*, as near as the diameter of the electrodes and the avoiding of short circuits will permit, in order to obtain a proper utilization of the heat of the arc. As no material except carbon in the form of graphite will resist under these conditions, an inner arch of graphite is constructed, to form the ceiling of the furnace chamber. As such a graphite ceiling, however, would cause great losses of heat on account of its great heat conductivity and, moreover, would be rapidly destroyed if exposed in an incandescent condition to the action of the air, a second arch of refractory material is built at a certain distance above the first. The space between the two arcs is intended to be filled with inert gases. This method of constructing the furnace chamber in three successive layers—graphitic carbon, inert gases, and refractory materials, is stated to be an important point of the invention. A second important point of the invention is said to be the special combination of the furnace chamber, the

electrodes of the arcs, and the charging channels, the combination being characterized by the shape, the dimensions and the relative situation of the various parts composing the whole. The length of the charging channels should be as great as possible, in order to utilize the heat radiated directly over a maximum heating surface, and to recuperate a large portion of the heat carried off by the gases and vapors issuing from the furnace chamber and rising through the channels in a direction opposite to that of the advancing layer of the charge. The angle of the slope of the channels should be such in each particular case that according to the density and the shape (granular, ovoid, brick-shape) of the charge, the materials to be treated slide along the bottom as the portions nearest to the arc melt, so as to produce continuous and uniform advance of the charge. The two arcs, with which the furnace is provided, are situated near the ends of the furnace in such a position, that about one-half of the heat furnished by each arc strikes directly the walls of the corresponding charging channel and the material under treatment which it contains, while the other half heats the furnace chamber proper. The distance of the two arcs from each other depends on the strength of the current and on the material under treatment, the length being such in any case that the central part of the chamber farthest from the electrodes is maintained sufficiently hot so that the molten materials which accumulate on the hearth may remain at the proper temperature. A tapping-hole and a slag-hole are provided. The gases generated in the furnace escape through chimneys fitted with throttle valves, which serve for the maintenance of a pressure slightly above that of the atmosphere inside of the furnace, in order to prevent air from penetrating into the latter and cooling or burning the electrodes and other carbon parts, or acting unfavorably on the materials under treatment.

Electric Furnace.—Michael R. Conley, New York, assignor to Electric Furnace Co., New York. Patent 769,250, September 6, 1904. Application filed October 1, 1902.

The furnace shown in cross-section in the adjoining Fig. 2 belongs to the resistance type and consists of a receptacle A,

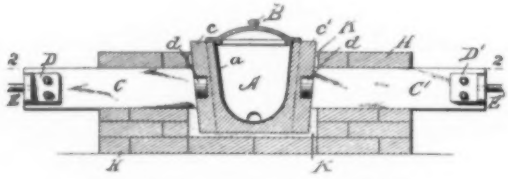


FIG. 2.—CONLEY ELECTRIC FURNACE.

which contains the material to be treated. It may be in the form of a crucible as shown in the figure, or of a cylinder, in which latter case the cylinder rests upon a block of some non-conducting substance as fire brick. The receptacle is made of a mixture of graphite, silica and fire clay, as in an ordinary graphite crucible. It is made under heavy pressure in a mold, and is not spun or turned as the ordinary graphite crucible, inasmuch as the latter method of manufacturing leaves minutes cavities in the finished article. The latter are harmless in the ordinary graphite crucible, but they tend to produce arcs, when an electric current passes through the crucible, whereby large holes are formed which would render the crucible useless. The receptacle is provided with an insulating lining *a*, so as to prevent the current from being short-circuited through the metal or other contents of the receptacle. The insulating lining consists of a composition which becomes plastic when subjected to a high degree of heat and tends therefore to close up any cracks in the receptacle. The material of which this lining is composed is not disclosed. The receptacle is approximately uniform in thickness, and is provided with an extension or wing on each side, which is approximately uniform in cross-section, and reaches from the top to the bottom of the receptacle. Into these extensions the tenons *d d'* of the carbon arms C C' are mortised, for which latter the extensions serve as supports. Their further object is to form conductors which tend to distribute the current vertically and to widen its path, thus preventing a local overheating and the formation of cracks, which would result if the current were allowed to flow in a narrow zone, as it would do if the extensions were omitted. A tight joint between the arms *c c'* and the receptacle is obtained by means of a cement, consisting of graphite and a hydrocarbon such as molasses. This cement is carbonized by the application of heat, with the result that the arms and the receptacle become a practically unbroken path for the current. Metallic plates D D' are bolted to the arms C C', which serve as connection for the leads E E'. The receptacle A and the arms C C' are maintained in proper relation to each other by means of brickwork H. A non-conducting substance K is packed around the receptacle in order to support its walls and to prevent radiation of the heat. Fire clay in a powdered or granulated form has been found to be well adapted in not only preventing radiation, but also in preventing arcing, as when an arc starts in the furnace wall, the comminuted fire clay falls into the place eaten out by the arc and sticks close to the furnace. It is stated to have been found that if the material of the furnace has only sufficient conducting matter to cause the current to start through it when the furnace becomes hot, the current will continue to traverse and heat it, even though the conducting matter is burned out. A diagrammatic arrangement which is stated to be well adapted to practical use shows the furnace connected in the secondary circuit of a step-down transformer, a variable choke coil being included in the primary circuit for controlling purposes. Furthermore, only a portion of the receptacle may be of conducting material, while the rest may consist of a non-conducting substance.

Storage Batteries.

Method of Rendering Storage Battery Gases Non-Explosive.—Thomas A. Edison, Llewellyn Park, N. J., assignor to Edison Storage Battery Co. Patent 767,554, August 16, 1904. Original application filed November 28, 1902. Divided and refiled June 13, 1904.

Fig. 3 illustrates a section view of one of Mr. Edison's improved storage battery cans provided with an arrangement

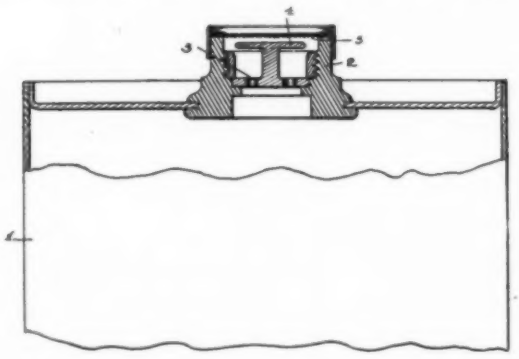


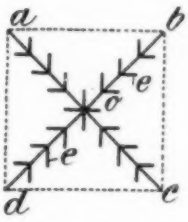
FIG. 3.—EDISON BATTERY.

for rendering the gases non-explosive. The can 1 of thin nickel-plated steel is provided with a neck 2. A perforated plug 3 disposed within this neck carries a deflecting plate 4 for the purpose of diffusing the gases which escape through the perforations. The gases are deflected by the plate and are comparatively attenuated. At the top of the neck there is arranged a suitable cooling medium, as wire gauze, through which the gases escape in a highly rarified condition. Even if they could ignite on the outside of the gauze, the radiating

capacity of the latter is suciently great to prevent its becoming hot enough to ignite the gases below it. No explosion can therefore take place. This is stated to be especially true when the deflector is used, since otherwise there would be danger of a small stream of gas passing directly from each perforation through the gauze in a sufficiently concentrated condition as to result in the gauze being dangerously heated. The method above described can be used in connection with the method of separating entrained globules of liquid, as described in Mr. Edison's patent 764,183, of July 5, 1904, which is described and illustrated in Electrochemical Industry, Vol. II., page 325.

Electric Accumulator.—Constantin de Sedneff, Paris, France. Patent 768,630, August 30, 1904. Application filed July 28, 1902.

The plates of this accumulator are constructed of a number of elements, one of which is illustrated in Fig. 4. It is composed of two diagonals *a b c d*, from which project branch ribs *e* set at forty-five degrees with regard to the diagonals, *i. e.*, parallel to the sides *ab*, *bc*, *cd*, *da*, respectively, of the square. The paste fills up all the space inclosing the diagonals and ribs. The two diagonals are said to give a contact surface which has 1.41 times the surface of the square frame *abcd*. The ribs, which increase the surface to four times that of the square *abcd*, are set at equal distances from one another and have a uniform degree of projection. The projecting portions of the ribs are equal to their spacing; that is, each rib *e* terminates at a point at right angles or opposite to the root or beginning of the preceding rib, so that the ribs as a whole form a kind of staircase device. Thus, on the increase in volume of the oxide due to peroxidation, the development of considerable mechanical efforts tending to deform the support is prevented. As the expansion moreover takes place in a direction parallel to the ribs *e*, the active matter preserves, in spite of the variations of volume, a permanent contact with the conductive support, and at all points of the latter. The expansion being equal, as the figure is symmetrical around its center *o*, the support cannot undergo any deformation, as the results of the expansive efforts is nil. Instead of having the form of a square, the elements can be of any other geometrical form, *f. i.*, triangular or hexagonal. In all the forms, however, the angular direction of the ribs with regard to the diagonals constitutes a feature of considerable importance, inasmuch as its object is to give the resultant of the mechanical efforts due to the expansion of the oxides such a direction as to prevent any undesirable influence upon the cohesion of the active mass or the contact between the latter and the support. This arrangement is claimed to lead to a considerable improvement in results when compared with those obtained by the majority of large surface plates, as, *f. i.*, those of the Tudor accumulator, in which, if it is built without a core, the expansion takes place perpendicularly to the ribs, which are strongly compressed, while, if the accumulator has a core, the oxide layer is forced back perpendicularly to the ribs, owing to a slight inclination of their faces, and drops. An alternative form of electrode is described in the specification, in which the ribs *e* are continued downwards in a longitudinal direction, so that a prismatic body is formed, of which a figure like the one illustrated would represent a cross-section. This is employed when the battery is intended for a slow charge and rapid discharge or *vice versa*, in order to increase the external surface of either the negative or positive plate. Stress is also laid upon the fact that the weight of the active mass is made equal for both electrodes, and that the proportion between the weight of lead and that of the active mass is the same.



STORAGE BATTERY ELEMENT

Galvanic Elements.

Electric Battery.—P. J. Kamperdyk, New York. Patent 768,372, August 23, 1904. Application filed October 14, 1903.

The cell is of the zinc carbon type, the negative pole electrode being a zinc plate, while the positive electrode is composed of groups of small carbon pencils, secured at their ends to metal plates and arranged in parallel rows. The carbon electrodes are placed in porous cups, open at their bottom and held in place by forcing their lower end into a layer of softened asphalt or like material, which covers the bottom of the vessel. Several cups are arranged in each cell. The cups are preferably made of carbon and connected to the positive elements, so as to increase the surface of the electrode. A system of piping connects the interior of all the cups and provision is made for causing the flow of the depolarizing liquid contained in the cups from one to the other. Another system of piping connects the various vessels constituting a battery among themselves, thereby affording a means for an independent circulation of the battery electrolyte, so as to maintain the latter at a uniform density.

Galvanic Battery.—A. J. Jacobson, Hamburg, Germany. Patent 768,180, August 23, 1904. Application filed March 19, 1903.

The cell consists of a cylindrical vessel of zinc or other metal. Within this vessel is placed a carbon electrode of preferably cylindrical or prismatic cross-section. The space between the vessel, which acts as one electrode, and the carbon electrode is filled with blotting paper or similar matrial which is intended to suck up and keep the electrolyte. The cell is closed by a removable lid. It is claimed that the arrangement of a removable cover at one end of the cell affords the great advantage, that such a cell can be kept dry until immediately before its first use, whereby greater efficiency and duration of the cell are secured.

Miscellaneous.

Connector for Electrochemical Apparatus.—O. P. Fritchle, Denver. Patent 768,175, August 23, 1904. Application filed Dec. 28, 1903.

The connector consists of a heavy copper wire sheathed with lead, except at its ends. These ends dip into nickel-plated mercury cups, which are fastened to the electrodes which are to be connected. The ends of the lead sheath on the copper wire are formed into bulbs. A soft rubber sleeve fits closely upon the bulbed ends of the coupler sheath and the mercury cups. This arrangement allows either electrode to vibrate without transmitting the vibrations to the other electrode, the coupler being supported entirely by the rubber sleeve.

Electrical Apparatus for Cleaning Gas.—C. G. Hardie, Hamburg, N. Y. Patent 768,450, August 23, 1904. Application filed November 12, 1903.

The apparatus is intended for cleaning producer, blast furnace and other gases, by precipitating from them the impurities which they contain. The apparatus consists essentially of a long metallic box with an inclined bottom. It is connected with one terminal of a high-potential transformer and is provided with an inlet opening for the introduction of the gases and an outlet. A stream of water runs down over the bottom of the box. Inside of the box there is arranged another electrode in the shape of a flat plate, which is connected to the other transformer terminal. It is insulated from the box by means of glass. It is stated that during the operation of the apparatus, the impurities are thrown towards the bottom of the box and are there caught by the water and washed away.

While the Canadian Copper Co.'s plant is at present operated by steam, the Huronian Co. is to construct a big hydraulic plant at Turbine, Ont., with electric power transmission over 30 miles to Copper Cliff.

SYNOPSIS OF ARTICLES IN OTHER JOURNALS

A Summary of Articles on Electrochemistry and Allied Subjects Appearing in American and Foreign Periodicals.

Industrial Electrochemistry.

Ozonizers.—The production of ozone by silent discharges through air, and the utilization of ozone for the sterilization of water seems to attract considerable interest at present. Various notes on this subject have been published in our columns. In the London *Electrical Review*, of August 19, J. B. C. Kershaw gives descriptions of various processes of this kind. Fig. 1 is a sectional elevation of the Marmier and Abraham form of ozonizer. A is an air-tight box about 2½ meters in height, containing a number of vertically-placed electrodes, *e e e*. These electrodes are hollow plates of steel, and each carries on its two external faces, plates of glass, *i i i*. The electrodes are placed in the box or chamber A in such a manner that a considerable air space separates each neighboring pair. The air supply takes place by the central channel O, and the arrows in Fig. 1 indicate the direction taken by the air in its passage between the electrodes and out of the chamber, by the passage D. The hollow electrodes are cooled by a current of water which flows through them, special arrangements being made to avoid short-circuits through the water supply. Current at 40,000 volts is used for this type of ozonizer, and an external spark-gap is employed to minimize the danger from spark formation in the ozonizer. As regard yield, 1 hp.-hour was stated to produce 20 grams of ozone, and to ozonize 3.4 cubic meters of air at Lille, while at Marseilles an installation in a brewery is said to be producing a concentration of 12 grams of ozone per cubic meter of air, with an initial pressure of 30,000 volts and a discharge equivalent to 5 kw. per square meter of electrode surface. Installations of this ozonizer for water purification are in use at Lille and at Marseilles.

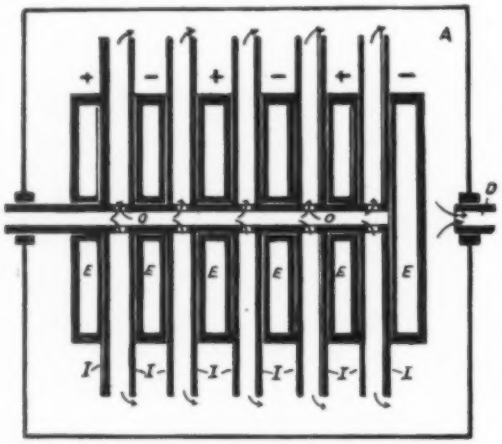
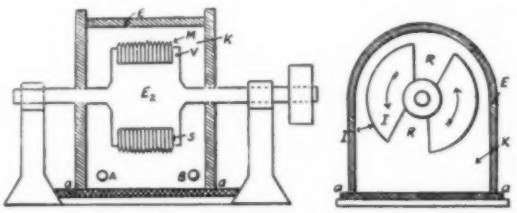


FIG. 1.—MARMIER-ABRAHAM OZONIZER.

Figs. 2 and 3 are sectional diagrams of Otto's latest form of ozonizer. K is a semi-circular air chamber, with a metal wall, E_1, which forms one electrode. Within this chamber a number of steel discs, *S S S*, are mounted upon a revolving barrel, E_2, the edges of these discs being bevelled, and having the serrated appearance, shown in Fig. 2 at M. Each disc has two segments cut out as indicated at R, R (Fig. 3), and the plate of insulating material (glass), *a*, *a*, which forms the base of the chamber K, in conjunction with these gaps, effectually destroys any arcs that may strike across the air space, I, I. The air enters the chamber K by B, and passes away at A_1. The rapid rotation of the composite electrode E_2, with its serrated edges, assists in distributing the air through the interior of the ozonizer, before its escape at A. The distance separating the two electrodes should be about 30 mm., and with steel discs 1½ mm. in thickness, having bevelled edges 10 mm. broad, a pressure of 25,000 volts can be employed. The Otto form of ozonizer is employed at one or two factories in France in connection with the manufacture of organic products, and the inventor has recently been carrying out some experiments with it at Niagara Falls in relation to water purification.



FIGS. 2 AND 3.—OTTO OZONIZER.

The author then deals with the Siemens & Halske ozonizer and the Vosmaer-Lebret ozonizer, which were described at some length in our vol. I., page 179 and 31, respectively. Mr Kershaw concludes the article with the following general remarks. The fact that ozone is formed when the silent electric discharge is allowed to pass through air, or through pure oxygen gas, has been known since the early days of electrical science. The work of recent inventors and experimenters in this field of research, therefore, has been simply directed toward devising forms of apparatus which would be capable of practical application when dealing with large volumes of gas, and toward reducing the losses arising from spark formation and decomposition of the ozone already formed. The methods which have been adopted by different inventors to avoid the danger of spark formation vary greatly. In nearly all the ozonizers glass is used as dielectric between the electrodes. In some, a spark gap is provided in the external circuit, and if the conditions in the ozonizer proper should at times lead to sparking, the main discharge occurs in the external spark gap. Other inventors make use of rotating electrodes, which vary in distance, or in which segmental openings have been made. Should sparking occur with these electrodes, the arc is speedily broken by the increasing distance or by the gaps produced by the rotation of the electrode or electrodes. A third group of inventors use air currents sufficiently rapid to blow out any sparks that may form between the two electrodes, while yet another plan is to use a choking coil in the external circuit, which will not permit the current necessary to maintain an arc to pass into the ozonizer.

Electrometallurgy of Iron and Steel.—Stahl und Eisen of August 15, contains the conclusion of B. Neumann's serial on the use of electric furnace methods in the iron and steel industries. After giving some data on the cost of various processes, he sums up his conclusions. He believes that in the principal iron industry countries, like the United States, Germany and England, which have an abundance of fuel, but only impure iron ores, the electric furnace cannot be expected to become a serious competitor to the blast furnace for the production of pig iron. The conditions are different in countries in which fuel is scarce and where pure iron ores and sufficient water power are available; this is, for instance, the case in South America and New Zealand; in such countries the production of pig iron in electric furnaces may be an economical success. But even in countries like the United States and

Germany the electric furnace may be used advantageously for making high-grade ferro-alloys. He also believes that the electric furnace is capable of replacing the present expensive methods for making crucible steels. Since we will publish a special article on this subject by the same author in one of our next issues, these brief notes must here suffice.

Starch.—In the *Elektrochemische Zeitschrift*, of September, E. LECONTE describes an electrolytic starch process which is stated to be in use by the Compagnie Electro-Sucrière in Paris. The rice is first treated three times in sodium hydroxide solutions of decreasing concentration, and is then washed four or five or more times with water each time for several hours. The water is then drawn off and the rice brought to the mill. The dough-like mass, which comes from the mill, is diluted to 4 or 6° Be. and brought on a sieve; a caustic soda solution is added to bring the alkalinity of the "starch milk" to about 1 gram of soda per liter. It is then brought into the electrolyzers which contain vertical electrodes of "aluminium, zinc or any other suitable metal." The electrodes are connected in parallel, but the voltage and current used are not stated. The electrolyzer boxes taper toward the bottom from which the solution is drawn off by pipes, to be brought in very fine sieves, which separate the "organic deposit formed by the action of the current." The starch is collected on inclined surfaces and is stated to be nearly absolutely pure and very white.

Aluminium.—According to a note in *Journal de l'Electrolyse*, August 1, a company has been founded, backed by German Banks and the Italian Society of Electrochemistry, for the utilization of Italian bauxite and the manufacture of aluminium, water power to be utilized in the valley of Pescara.

Magnetic Separation.—The London *Coal and Iron Trades Review*, of July 15, contains an illustrated description of several types of the Wetherill magnetic separator, with an account of the method of working in a German metallurgical plant.

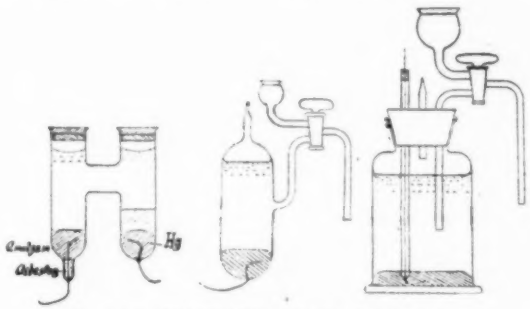
THEORETICAL AND EXPERIMENTAL.

Construction of Standard Cells and Mercury Electrodes.—Of various containing vessels, proposed for standard cells, the H-form has been found most valuable, since in this case the electrolyte always remains saturated in proximity to the electrodes. The ordinary construction, however, with platinum wires fused into the glass has the disadvantage that after some time the vessel cracks on the amalgam side. This is due to the fact that the zinc or cadmium diffuses into the wire which is thus made to expand. Of course, this advantage may be overcome by using a bent capillary tube and passing the wire through it; but the vessel is then very fragile. N. T. M. WINSMORE, in *Zeit. f. Elektrochemie*, September 2, describes the following very simple and effective device which is illustrated in Fig. 4. The leg containing the amalgam is provided at its lower end with a narrow continuation which is filled with purified pressed asbestos which prevents the amalgam from reaching the point where the platinum wire is fused into the glass. The author states that the small amount of air remaining in the asbestos is not detrimental; standard cells of this construction maintained their e. m. f. constant for more than a year and a half. Figs. 5 and 6 represent devices for mercury electrodes, which the author has found very suitable. The cock is a three-way cock. H. DANNEEL describes in the same issue a device by which diffusion of a foreign salt into a standard electrode is prevented by maintaining the connecting siphon under a sufficiently strong hydrostatic pressure.

Mercurous Sulphate in Standard Cells.—In connection with the recent work of Dr. Wolf and Professors Carhart and Hulett, the results of an experimental investigation of the same subject made in the (British) National Physical Laboratory is of interest. The results are embodied in a report of the committee of standards for electrical measurement to the British Association, printed in the London *Electrical Review* of September 9. The work on mercurous sulphate was done by F. E. SMITH. Smith has amply confirmed the result of previous investigators that the greater part of the difficulty in obtaining entirely concordant results for the various cells set up by different experimenters is due to the mercurous sulphate. He describes three methods of preparing the paste which lead to identical results, and which have the advantage that cells set up with these pastes have the same e. m. f. within one or two hundred thousandths of a volt immediately after manufacture. In the first method due to Divers and Shiridzu, the paste is prepared by the action of fuming sulphuric acid on mercury; in the second, following Carhart, it is prepared by the electrolysis of weak sulphuric acid and mercurry as anode; while in the third mercurous sulphate is dissolved over a water bath in sulphuric acid. The acid solution is then poured into a large volume of distilled water, and the mercurous sulphate is precipitated in a pure form. In all cases it is important that as advised by Swinburne and Carhart, the salt should be washed, for a Clark cell, with zinc sulphate, and for a cadmium cell with cadmium sulphate, and not with distilled water.

Silver Voltameter.—In connection with K. E. GUTHE's Congress paper, abstracted on another page of this issue, an article of the same author in the August number of *Phys. Review* should be of interest. He describes various types of voltameters and their treatment, gives the results of an experimental comparison of the different types, and finally deals with the electrochemical equivalent of silver.

Rotating Cathode for Electrical Work.—A further contribution to this interesting subject is published in the *American Journal of Science*, of September, by H. E. MEDWAY. The author had formerly, in co-operation with Gooch, described a method for the rapid electrolytic precipitation of metals upon a rotating platinum crucible as a cathode. He has now made experiments to see whether platinum may be replaced by cheaper metals. He finds the silver crucible may, with some economy and without sacrifice of accuracy, be substituted for the platinum crucible. On the other hand, in experiments with a nickel crucible, he found that the ease with which the nickel is attacked both during the analytical process and in the subsequent removal of the deposit, is a bar to the use of the metal for a rotating cathode. Shepherd has recommended the use of the ordinary disc anode of platinum as the rotating cathode, in place of the platinum crucible, while a stiff platinum wire, carried in semi-circular conformity to the edge of the disc cathode, serves as the anode. The present author states that with this form and adjustment of apparatus, the deposits obtained are not so adherent as might be desired, and tend to crumble away from the edge of the disc; and the same thing is true of discs of copper and silver. The probable reason for failure to obtain an adherent deposit is that the edge of the disc, being nearer the anode, receives more current and larger deposit of copper than the central portions, with the consequence that the deposit upon the edge, built out and fragile, tends to break off under the rapid rota-



FIGS. 4, 5, 6.—STANDARD CELLS AND MERCURY ELECTRODES.

tion of the disc. To remedy this defect the present author used for an anode a strip of platinum extending across the cell under and parallel to the rotating disc, so that the current may be equalized all over the disc. Very good results were thus obtained in the precipitation of copper. The attempt to substitute aluminium for platinum, was not successful, owing probably to the film of aluminium oxide always present. From his experience he concludes that the disc is inferior to the crucible for use as a rotating cathode.

Carbon Cell.—The full account of the experimental investigation of F. Haber and L. Bruner, which is the subject of their recent Congress paper (see the abstract on another page of this issue) is published in *Zeit. f. Elektrochemie,* September 9.

Ionic Transference Phenomena in Fused Salts.—On the basis of the hypothesis that the conduction of an electric current through an electrolyte is accomplished by cations and anions moving in opposite directions, Hittorf has shown, long ago, that the ratio of the two velocities may be determined by measuring the local concentration changes at the two electrodes. The ratio of the velocity of the cation to the sum of the velocities of cation and anion is called by him the transport number of the cation. These investigations of Hittorf became later the foundation of Kohlrausch's classical researches which lead him to his law of the independent migration of the ions. R. Lorenz and G. Fausti publish in *Zeit. f. Elektrochemie,* August 19, an interesting account of experiments in which they endeavored to determine to transport number in fused salts. They experimented, of course, with mixtures of fused salts, and their first experiments were of a purely qualitative nature. When a fused mixture of equal equivalents of NaCl and KCl with a little $PbCl_2$ was electrolyzed, the cathodic compartment showed a loss of Pb greater than the deposited quantity. When a mixture of much KCl and a little $PbCl_2$ was electrolyzed, the cathodic compartment showed again a loss of Pb while the potassium chloride had increased. The authors then electrolyzed a mixture of equivalent quantities of $PbCl_2$ and KCl and endeavored to determine the transport number of potassium quantitatively at 800° C.; in one experiment they found the value 0.36, in another 0.19.

Thermo Electromotive Force of Nickel Nitrate.—In the August number of *Physical Review,* J. F. Meyer gives the results of measurements of the thermo-electromotive force of nickel nitrate in four different organic solvents. In aniline pyridine with platinum electrodes it is zero through a temperature range of about 80° C. In a solution of nickel nitrate in alcohol the heated electrode is first positive and then becomes negative toward the cold electrode, while in acetone solutions the heated electrode is always positive. The thermo-electromotive force is independent of the concentration from 1/10 to 1/50 normal. The author remarks that polarization effects cannot be avoided and they are large enough to mask the thermal effects in the measurements. He suggests to measure the degree of dissociation in these organic solvents by determining the molecular conductivity. A possible relation between thermo-electromotive force and dissociation might thus be quantitatively shown.

The Constant of the Gas Law.—The *Zeit. f. Elektrochemie,* August 19, contains a paper by D. Berthelot, on the most probable value of the constant R in the law for perfect gases $pv = RT$. If v is the volume of one grammolecule of gas, p the pressure in atmospheres at the absolute temperature T on sea level and in the geographical latitude of 45°, then, according to Berthelot, $R = 0.08207$ with a possible error of about 1/8000. With reference to this paper, W. Nernst gives in the same issue some further figures. From $R = 0.08207$ [liter $\times$ atmosphere $\times$ T^{-1}] he derives $R = 0.83155 \times 10^8$ (ergs $\times$ T^{-1}) and $R = 1.98507$ (gramcal. $\times$ T^{-1}). The often used formula for calculating electromotive forces (based on Nernst's theory)

$$\text{e. m. f.} = \frac{RT}{n} \ln \frac{C}{c} \text{ becomes then}$$

$$\text{e. m. f.} = \frac{0.86134 \times 10^{-4}}{n} T \ln \frac{C}{c} = \frac{0.00019833}{n} T \log \frac{C}{c} \text{ volts.}$$

where ln means Naperian logarithms (basis e) and log means ordinary logarithms (basis 10).

Batteries.

Auxiliary Electrodes for Measurements.—The e. m. f. of a storage battery gives a general indication of the state of charge or discharge. But in some cases it is important to be able to determine the condition of a single plate, either the peroxide plate or the spongy lead plate. For instance, when a new type of battery is constructed, it is important to balance the two plates, so that the peroxide plate and the spongy lead plate, when discharged, become exhausted simultaneously—not one plate a long time ahead of the other. For such tests it is useful to measure the single potential of each plate against a small auxiliary electrode suspended in the acid; the plate under test and the auxiliary electrode are then connected to a voltmeter. An article, by C. Liagre, on the use of such auxiliary electrodes is published in *L'Eclairage Electrique,* September 10. For practical purposes which do not require utmost accuracy, a small amalgamated zinc rod is sufficient, but an amalgamated cadmium rod is better. With a density of 1.200 of sulphuric acid, the potential of zinc against peroxide of lead is 2.43 volts, cadmium against peroxide of lead 2.19 volts, zinc against spongy lead 0.40 volt, cadmium against spongy lead 0.16 volt. The potential of the zinc or cadmium electrode may vary by a few hundredths of a volt on account of variations of the concentration of zinc sulphate or cadmium sulphate in proximity of the auxiliary electrode. In practice the results obtained with zinc or cadmium are sufficient, and these forms of auxiliary electrode are easily made and used. Other metals, such as copper, iron, nickel, silver, may also be used as auxiliary electrodes, but they have the disadvantage that by their presence in the solution they may cause local discharges of the negative plate. For most exact measurements auxiliary electrodes should be used in which one of the ions of sulphuric acid, either H or SO_4, is active. The author describes the hydrogen electrode and the mercurous sulphate electrode. A very practical auxiliary electrode is a small, spongy lead plate or a small lead peroxide plate which, however, must be well charged, before they are used. The author gives a diagram showing the relation between the potential of the different auxiliary electrodes H, Zn, Cd, Cu, Hg, Pb, PbO_2.

Theory of Lead Accumulator.—Gladstone and Tribe's double sulphate theory of the lead accumulator is now generally accepted and has been confirmed especially by the extended researches of Dolezalek. However, concerning the details of the ionic mechanism, there exists still disagreement as indicated by the different theories of Elbs, LeBlanc and Liebenow. *L'Eclairage Electrique,* September 3, P. Bary proposes a new hypothesis, the essential point of which is that lead sulphate in solution, under the action of the current, gives peroxide at one side, and spongy lead at the other side after the fashion of all soluble lead salts.

Storage Batteries for Traction.—In London *Electrical Review,* September 9, W. N. Stewart proposes the uses of storage batteries on trains for long-distance electric railways. He wants to employ on a heavy train two sets of motors; one set—for instance, single-phase motors—being supplied from the transmission line; the other set—direct-current motors—from a storage battery on the train itself. The single-phase motors are kept in continuous operation, irrespective of the contour of the line, while the direct-current motors would assist the former only in starting and on upward gradients, while they are used as generators to return current to the battery on downward gradients and in braking, by means of a regenera-

tive system. He claims that the first cost of installation and operating expenses would be smaller for such a mixed system than for a pure single-phase system. From statistics of lines in Italy, where batteries were used on trains, it appears that they were operated nearly 30 per cent cheaper than similar lines using steam locomotives; but the cost of looking after these batteries, exclusive of the cost of renewal plates, was practically as great as the total cost of charging current. The author pins his faith on the Edison cell, which will practically need no skilled attendance and which shows no deterioration.

MISCELLANEOUS.

Magnetic Alloys Composed of Non-Magnetic Metals.—The *London Electrician*, August 26, contains some notes on a British Association paper by R. A. HADFIELD, describing the alloys discovered by Heusler, which, though composed of the non-magnetic metals copper, manganese and aluminium, possess considerable magnetic powers. The best results with a given percentage of manganese are obtained when the percentage of aluminium is roughly one-half that of the manganese—*i. e.*, with one atom of aluminium to one of manganese. An alloy exhibited contained 60 per cent copper, 26 per cent manganese and 14 per cent aluminium, and was magnetically nearly equal to cast iron. Unfortunately, it is very brittle and all attempts to draw or forge it have failed. In the discussion which followed it was mentioned that non-magnetic alloys containing as much as 88 per cent of iron had been produced and that a certain amount of aluminium increases the magnetizability of iron. Glazebrook asked whether cooling curves had been taken and suggested that manganese may be magnetic at exceedingly low temperatures, and that the copper and aluminium alloyed with it may raise the temperature at which the magnetism disappears. Hadfield said that adding iron to this alloy would give it the character of a manganese steel and, therefore, make it non-magnetic. This implies, paradoxically enough, that iron may be added to a magnetic metal so as to abolish its magnetic properties.

Special Steel.—A paper of METCALF, read before the American Society for Testing Materials and published in the August number of the *Iron and Steel Magazine*, gives an outline of our present knowledge of this subject. The analyses of two kinds of high-speed steels are as follows: A tungsten steel contained tungsten 9.99 per cent, chromium 2.83, carbon 0.60, phosphorus 0.10, sulphur 0.10, silicon and manganese traces; a molybdenum steel contained molybdenum 9.65 per cent, carbon 0.65, phosphorus 0.016, silicon 0.046 and manganese 0.22.

On account of limitations of space a number of abstracts had to be reserved for our next issue.

RECENT METALLURGICAL PATENTS.

GOLD.

The cyanide process has long been known to have its limitations. For instance, when refractory ores, such as tellurides, are treated with a cyanide solution, the extraction is imperfect. H. R. Cassel (U. S. patent 769,938, September 13) proposes to add bromide of potassium to the cyanide solution and introduce chlorine gas into it slowly and gradually. The gold will thereby be rapidly dissolved, the reactions being stated to be as follows:

$$Cl + KBr = KCl + Br$$
$$Br_2 + 4KCN + 2Au = 2KAu(CN)_2 + 2KBr$$

H. S. Stark (769,280, September 6) patents a process for the extraction of gold from pyritic auriferous ores which is stated to be particularly applicable to the recovery of gold from the residues resulting from the treatment of such ores by ordinary cyanide solutions. The method consists of treating the previously crushed ore with a solution of sulfocyanide of an alkali metal in the presence of an oxidizing agent, including atmospheric oxygen. This latter, assisted by the inherent acidity of the ore, brings about a slow decomposition of a portion of the sulfocyanide, resulting in the production in close proximity to the gold particles of nascent cyanogen and hydrocyanic acid. Both of these substances are powerful gold solvents, and thus upon their formation dissolve out any adjacent metallic gold, which is thereupon carried into the sulfocyanide solution. This solution is subsequently leached out of the ore and its contained gold separated from it by any suitable means.

S. C. C. Currie (769,254, September 6) patents a process of treating sulphurets by a step-by-step method. The ore is crushed and may be concentrated. Then in a raw state it is subjected to the action of steam or heated hydrogen gas, whereby sulfureted-hydrogen gas is thrown off which is stored for further use. The ore is then roasted in a suitable furnace. While still hot, it is then immersed in a hot caustic alkaline solution, such as caustic potash or caustic soda, whereby many of the soluble substances such as the salts or oxides of lead, zinc or other base metals are dissolved. The alkaline solution is then thrown off into a separate tank and sulfureted-hydrogen is passed through it, whereby the base metals are precipitated. The ore from which the alkaline solution has been withdrawn is washed with water and is then ready for treatment by chemical agents for extracting the precious metals. "If a chlorine solution is used, the same may be obtained by the electrolytic decomposition of sodium chloride, and the same decomposition will produce caustic soda, an alkaline agent herein referred to, and hydrogen gas, also before referred to. The gases driven off from the ore in roasting may be mixed and used to form the sulfureted hydrogen referred to as a reviving agent for the caustic alkaline solution. Sulfureted hydrogen is also used to good advantage in many instances in precipitating gold and other metals from the chlorine solution."

ALUMINIUM.

A very peculiar process for making aluminium without the use of the electric current is patented by W. Ruebel (770,389, September 20). "For carrying the process into effect clay is used, which must be as pure as possible—that is to say, which must consist as much as possible of aluminium silicate. The clay is at first made red-hot at a temperature of about 1800° Celsius, then ground and mixed with a sulphur containing compound of calcium, such as gypsum or the like, or with a mixture by means of which such a compound is produced—such as, for instance, a mixture of phosphate of calcium (or a substance containing phosphate of calcium) and sulphuric acid. To this mixture a substance is added effecting the exclusion of the air from the surface of the mixture and containing carbon—such as, for instance, mineral oil, coal dust, waste mineral oil (residuum) or other similar substances. The mixture is put into a crucible or retort and is exposed to a temperature of between 1000° and 2000° Centigrade after the air has been excluded, which may be done, for instance, by covering the mixture with coal-dust, by a reducing flame, or the like. The time during which the mixture is exposed to the high temperature depends upon the quantity of the mixture and amounts to about one-half to two hours. After congealing the contents of the crucible or retort consists of two layers. At the bottom of the crucible or retort is molten metal, and this is covered by a layer of slags, which slags

are mostly not molten together, but are powdery. The aluminium metal so obtained contains cometimes more or less phosphates and sometimes also silicate taken up from the walls of the crucible. In order to obtain a very pure aluminium, it is smelted again with lime, or lime is immediately added to the mixture while still in the molten condition."

The reactions are claimed to be as follows: Aluminium silicate and calcium sulphide react to form aluminium sulphide and calcium silicate. This reaction is accelerated in the presence of phosphoric acid. Aluminium sulphide combines with carbon according to the equation $2Al_2S_3 + 3C = 4Al + 3CS_2$.

Iron and Steel.

In carrying on the basic open-hearth process of making steel it is usual to increase the basicity of the slag in order that it may more effectively remove some of the impurities from the metal, by adding lime or limestone to the bath. When, however, a certain amount of lime has been added, the slag becomes too thick, and if it is then desired to add more lime it has been necessary to use considerable fluorspar in order to increase the fluidity of the slag and to allow of more lime being used. H. Carlsson (768,265, August 23) patents a modification of this process in so far as suitable quantities of titaniferous iron ore are added in the basic open-hearth furnace. This addition, on account of the titanic acid present, makes the slag much thinner and thus serves the purpose for which fluorspar has previously been used. Moreover, the iron oxide of the ore acts to some extent upon the carbon in the bath to reduce the carbon contents of the same. The author believes that the higher the percentage of titanic acid in the ore, the better it is for his process.

J. B. de Alzugaray (768,551, 768,552, 768,553, August 23) patents the following process in which the ore and the materials to be mixed with it are first pulverized and then made into bricks or slabs. The main point of his process is stated to be that he mixes the puverized ore not only with reducing and fluxing materials, but also with a refining agent. His bricks are called "carburized," if, besides the ore and refining material they contain carbonaceous material. They are called "non-carburized" if the carbonaceous material is left out. In the second case the carbonaceous material is added to the blast furnace in the usual way. In the latter case the reducing material employed may be gas. He gives the following two formulæ of the constitution of his bricks:

Carburized Bricks.		Non-Carburized Bricks.	
Ore	65 parts	Ore	65 parts
Coke	25 parts	Fluorspar	5 parts
Fluorspar	5 parts	Sodium chloride.	2½ parts
Sodium chloride.	2½ parts	Silicate or slag.	25 parts
Lime	2½ parts	Lime	2½ parts

The author claims that by thus mixing and treating the ore, the elimination of phosphorus, sulphur and other injurious elements is effected. By the treatment of the bricks carburized and non-carburized separately, he contends that he produces a very high quality of pig-iron which he designates as "refined" pig-iron. By using the two kinds of bricks together or consecutively in the furnace, he claims to have a new process for producing steel. For producing ferro-alloys he mixes the bricks with the oxides of the metals to be added.

Roasting Furnace.

Roasting furnaces of the McDougall type are so constructed that in a cylindrical steel or iron shell which is lined with bricks roasting shelves are arranged one above the other, through the center of which a hollow shaft is inserted. To this shaft rakes or stirring arms are attached corresponding to the different shelves, by means of which the ore is not only stirred, but also moved so that it gradually drops from one shelf to the other until it is automatically discharged from the last shelf. Ottokar Hofmann (768,748, August 30) describes modifications of this furnace, the object being to provide for good cooling of the central shaft, for an efficient cooling of the stirring-arms, and to construct the attachment of the stirring-arms to the central shaft in such a way as to permit a quick and easy withdrawing and replacing of a defective arm.

The furnace, as shown in vertical section in Fig. 1, is arranged for roasting ores like zinc-blende, which require additional heat for completing the roast, and is therefore provided with more roasting shelves *A A A* than are usually found in a furnace of this type, of which the three lower

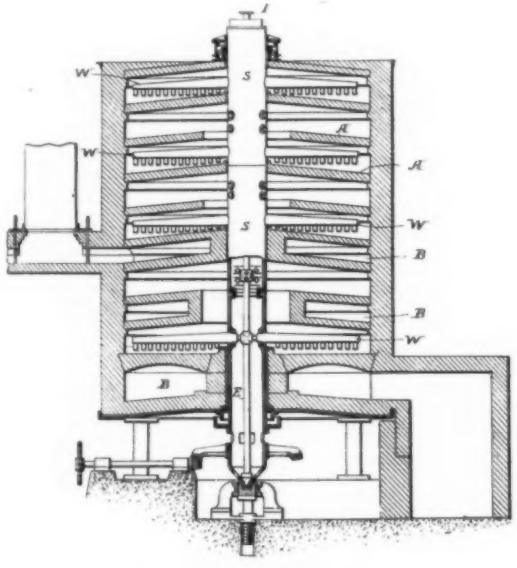


FIG. 1.—ROASTING FURNACE.

ones can receive additional heat by the three inserted fire-flue chambers *B B B*. The central hollow shaft *S* is provided with a number of recesses, two of which always correspond in their vertical location with the location of one of the roasting-shelves. They are placed diametrically opposite and serve for the insertion of stirring-arms *W*. Their position, however, in relation to the different roasting shelves is so that the arms in every succeeding shelf are horizontally at right angles with the arms of the preceding one, so that the ore dropping from one shelf to the other does not strike the rake. Mechanical details of construction are described by which it is easy to insert the arms *W* into the shaft *S*, a kind of "bayonet joint" being applied.

In the center of the hollow shaft *S* is inserted an iron pipe *E* (Fig. 2, which is of larger size than Fig. 1), which is provided with pipe fittings which permit the connections of small pipes *F* with the vertical pipe *E*. These connections are so arranged that the pipes *F* project out into the furnace through the center of each two opposite recesses. The foot end of the vertical pipe *E* is closed and provided with a square iron block. At the top the pipe *E* is connected with a stationary pipe *I* which in turn is connected with the air-pipe of a blower. Near the foot outside the furnace the hollow shaft is provided with openings. To start the operation, the starting arms are slipped over the pipes *F*, inserted in the recesses in the hollow shaft *S*. Then the blower is started. The air is forced through the branch pipes *F* into the starting arms at the furtherest ends, returns through the full length of the arms and leaves them to enter the hollow shaft where it unites with the upward current of air, which enters at the foot of the shaft through the openings provided there. By this arrangement an efficient cooling of the starting arms, as well as of the central shaft, is obtained. The hollow shaft *S* is constructed in three pieces, so as to facilitate repairs.

Apparatus for Wet Process.

C. H. Webb (768,319, August 23) describes a filtering apparatus consisting of a cylindrical vat which can be revolved. Within the vat a grating is formed of strips of wood which are placed diagonally across each other and secured to the internal surface of the vat at an angle to the axis of the barrel so that spaces are left between the strips of each layer. Over the gratings thus formed, a cocoanut matting is fastened. The same arrangement of grating and filtering cloth is provided at the ends of the barrel. The filter cloth may be protected by a layer of sand, spread thereon and kept in place by means of wire gauze. The ore is charged into the vat and the solution is run into it. The vat is then revolved while air is forced through the vat to accelerate the solution. Then, by turning a cock a difference of pressure is set up at both sides of the filtering cloth, so that the ores or slimes are drawn toward the cloth and become built up in successive layers upon the cloth. After the liquid has been withdrawn the residue is claimed to be comparatively dry.

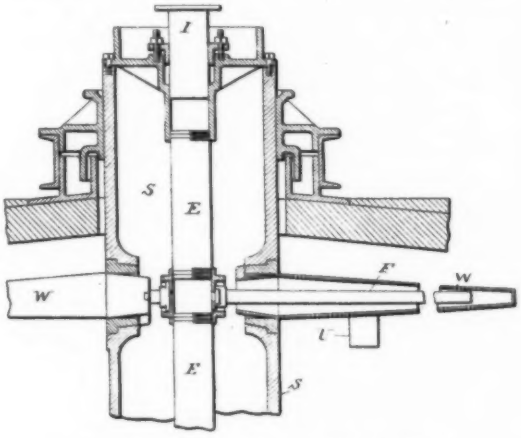


FIG. 2.—DETAILS OF ROASTING FURNACE.

L. S. Turner (768,094, August 23) patents a filtering apparatus for continuously separating metals from pulverulent ores. The essential features consist in making the filter-floor in the form of a ring or annulus, whereby an endless floor is obtained, and in moving this annular floor continuously above a correspondingly-shaped stational trough, which is divided into chambers that are alternately vacuum and compression chambers, air-tight joints being maintained at the edges of the trough, so that the material on the floor may be alternately subjected to the action of suction and blast as it passes above the different trough-chambers.

A. A. Stewart (770,332, September 20) patents an automatic valve for use in connection with leaching tanks, by means of which cyanide solutions, air, lime, gases and the like may be conveniently and uniformally distributed through the contents of the tank.

On account of limitations of space, a number of notes on patents had to be reserved for our next issue.

Germany's Chemical Industries.—According to a recent consular report, Germany's chemical industries have in 1903 worked as profitably as in former years. Some of the largest joint-stock companies declared from 24 to 26 per cent dividends on their share capital, besides carrying heavy amounts of their earnings to reserves and liberally writing off on their real estate and manufacturing plant. In the manufacture of dyes the German chemical works have almost a monopoly, supplying, as they do, their industrial competitors. The same may be said of synthetic indigo, which at this day already supplies more than one-half of the world's entire use.

Book Reviews.

Quantitative Chemical Analysis by Electrolysis.—By Prof. A. Classen. Fourth English from the fourth German edition, revised and enlarged by B. Boltwood. New York: John Wiley & Sons; 315 pages. Price $3.00.

The present edition, as pointed out by Dr. Boltwood, has been published with a view to include much new material, which has appeared since the fourth German edition, in 1897, of Prof. Classen's well-known book. The latter's recent work on "Ausgewählte Methoden der Analytischen Chemie" has therefore freely been drawn upon by the translator, and the arrangement of the present volume differs considerably from that of the fourth German edition on which it is based.

The treatment of the matters dealt with in the introductory chapters, viz., theory of solution, electrolytes, migration of ions, conductivity of solutions, etc., is based entirely on the dissociation theory. The wisdom of introducing the latter subject into a book, which is presumably devoted to practical analytical work, is seriously questioned, and it has been shown by Dr. E. F. Smith's well-known book on the same subject that an exhaustion treatment is very well possible without reference to any particular theory. It seems to the reviewer that the introductory chapter, instead of being amplified by the translator, might have been curtailed and the matter treated from a less, one might say, biased standpoint. The second part of the introduction deals with the measurements of potential and current, the sources of current, as cells, storage batteries, dynamos and thermopiles, and the apparatus for regulating the resistance. It also contains an exhaustive description of the various accessories for electrolysis, *i. e.*, dishes, electrodes, etc. Fourteen pages are devoted to an elaborate description of the former and present equipment of the electrochemical laboratory of the Royal Technical Institute of Technology at Aachen. The latter, with its complicated system of switches, fuses, resistances, etc., due to the employment of only one voltmeter and ammeter for a number of analyses, is decidedly inferior to the system used in this country, where each working place is provided with a set of the instruments, which are kept constantly in circuit while the analysis is going on.

The second part of the book contains the electroanalytical methods for the determination of the various metals, the determination of nitric acid in nitrates, the determination of the halogens, the separation of the metals and the separation of the halogens. Eleven pages are devoted to "some applied examples of electrochemical analysis."

Notwithstanding the above criticisms, the book in its present form is a valuable contribution to the existing literature on electroanalysis, and will well repay investment by anyone interested in the subject.

PYROMETERS SUITABLE FOR METALLURGICAL WORKS.

At the Barrow meeting of the (British) Iron and Steel Institute the suggestion was made that, in view of the growing importance of pyrometers to the steel industry, arrangements should be made to enable members to see the actual working of different pyrometers, in order to enable them to form their own opinions of the relative merits of the appliances available for metallurgical purposes. The council readily adopted this suggestion, and appointed a committee, consisting of Mr. R. A. Hadfield, vice-president, Mr. J. E. Stead, member of council, and Mr. B. H. Brough, secretary, to make the necessary arrangements for the exhibition. In the following we give an abstract of the report of the committee, according to the London *Electrician*.

1. *The Baird and Tatlock Pyrometer* (this description has been prepared by Mr. A. Campion, Cooper's Hill).—This is a

variety of thermo-electric pyrometer in which the e. m. f. developed by the difference in temperature of two similar thermo-electric junctions opposed to one another is measured. The Le Chatelier couple, consisting of a pure platinum wire and a platinum with 10 per cent of rhodium or iridium wire, is used. For use at very high temperatures, the platinum and platinum rhodium couple is preferable on account of its greater durability. The platinum and platinum-iridium couple gives a larger e. m. f., and consequently a more open scale. The measuring instrument is a portable form of high resistance dead-beat D'Arsonval galvanometer, the coil of which carries a long pointer over a graduated scale reading in degrees Centigrade or Fahrenheit direct. A special arrangement is adopted which prevents the pivots of the needle being damaged. In the stationary form of instrument the galvanometer is mounted on gimbals, and is therefore self-levelling. This form of instrument is very convenient when it is necessary to determine temperatures at different points in a large works. In both forms of instruments the moving part is a rectangular coil of fine wire delicately suspended between the poles of a powerful permanent magnet. The magnets, which are made from a special quality of steel, after being magnetized are very carefully tested for dead-beatness and permanency of readings before being made up. The thermo-couple wires are threaded through short lengths of double-bored porelain tubes, which, in turn, are enclosed in an iron or steel outer tube.

The instruments are very carefully calibrated before being sent out. The following is the method adopted: The increments of current furnished by the couple for equal increments of temperature are determined. The current corresponding to the maximum temperature (1,600° C.) which the instrument is to measure being known, a current of, say, 0.01 of the maximum is sent through the galvanometer, and the position of the needle is noted. The current is then increased by small amounts up to the maximum, and the position of the needle noted for each amount. In this way a scale corresponding to equal increments of current, and therefore to equal rises of temperature, is obtained. It then only requires the accurate determination of one point of the scale by a melting point temperature to render it an absolute temperature scale. The calibration of the instruments is not affected by being carried about. Two forms of recording instruments are also made, so that records of temperatures for lengthened periods of time may be obtained.

In the "pyrograph" a band of photographic paper is drawn at a suitable rate under a very fine slit in the dial. The slit is at right-angle to the motion of the paper, so that if the light of an 8-candle-power electric lamp is shining on the dial, some will pass through the slit and blacken the whole band as it is drawn past. The needle, however, of a dead-beat galvanometer actuated by the thermo-electric force of a platinum and platinum-rhodium couple moves above the dial, and this casts a shadow through the slit on the photographic paper, and when this is developed, the record is seen as a white line. The same clockwork which draws the paper also switches off the lamp for one minute every hour, and thus marks white hour lines across the record. A datum line, say at 1,000 deg., is marked on the record by a hair laid across the slit at the point, and by applying a scale to this line on the record the temperature at any part can be ascertained.

In the automatic recorder the needle fixed to a dead-beat galvanometer coil and actuated by a thermo-junction plays between two rubbing contacts. The torsion wire supporting the coil is hung from a differential gear connecting two pieces of clockowrk, and these are controlled by magnets worked by current sent through either of them when the needle completes a circuit through either of the rubbing contacts. The effect is to twist the torsion wire and bring the needle central between the contacts. A lever and pen is also connected to the differential gear, so that the amount of movement needed to bring the needle midway between the contacts is shown and recorded by the pen, which is arranged to write on a drum.

2. *Callendar and Griffith's Thermometers, Thermo-couples, etc.*—In resistance thermometers the increase in resistance of a platinum wire with temperature is observed. The electric-resistance thermometer was first proposed by Sir William Siemens in the Dakerian Lecture in 1871, and it immediately came into general use for metallurgical work. Unfortunately, it was found that small changes in the resistance of the thermometer occurred owing to the chemical action on the platinum of the silica in the porcelain bobbin on which the wire was wound. In 1886 Prof. H. L. Callendar showed that if the platinum is supported on a mica frame, in section, that of a cross with equal arms, there is perfect insulation without any cause of alteration. Prof. Callendar also pointed out the importance of protecting the platinum from noxious gases, all volatile metals attacking platinum readily. The Callendar and Griffith's resistance thermometer consists of a fine platinum wire wound on a mica frame, and connected by means of stout copper or platinum leads to terminals in the head of the thermometer. Two similar leads, but unconnected with the coil, pass through the whole length of the thermometer and act as compensating leads. By this means no error is introduced by the variation of the temperature of the wires connecting the thermometer with the indicator or recorder.

For reading temperature directly by means of a resistance thermometer, the Whipple temperature indicator is generally employed. It consists of a Wheatstone bridge, one arm of which is a long bridge wire wound in the form of a helix on an ebonite drum. A contact maker mounted on the inside of a drum can be rotated over this wire. A scale divided into degrees Centigrade or Fahrenheit is fixed on the outer surface of the drum. The four terminals of the resistance thermometer are connected by means of leads to the indicator, the resistance coil of the thermometer thus forming one arm of the bridge. By turning the handle, the contact maker is moved along the bridge wire until sufficient resistance is introduced to balance the resistance of the thermometer. The galvanometer needle shows the temperature on the scale previously referred to. This instrument has been applied with considerable success to the measurement of the temperature of hardening baths, boiler flues, etc.

On account of limitations of space this description is to be concluded in our next issue.

SUCTION GAS PRODUCERS.

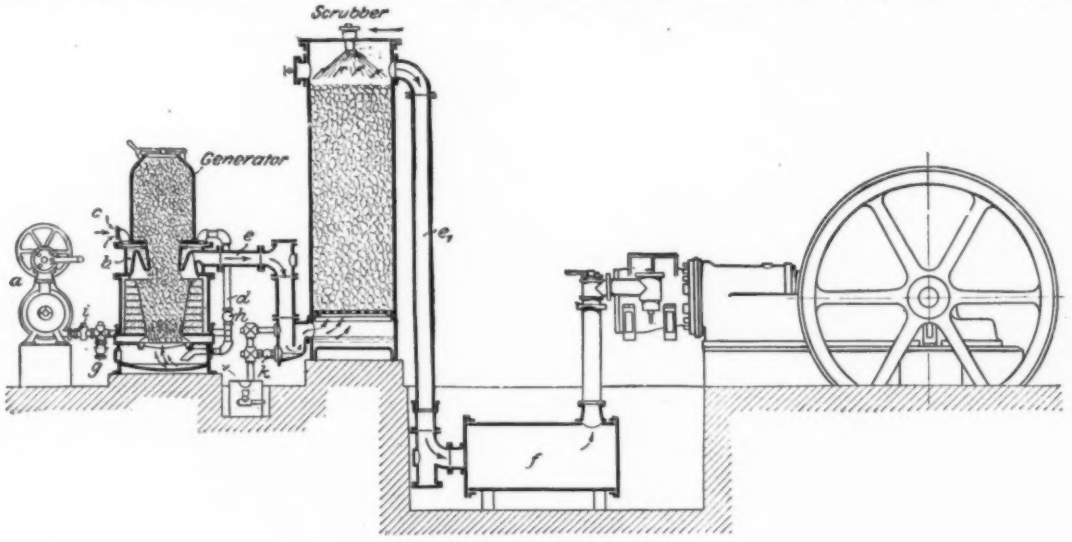
As an economical generation of power is essential for electrochemical industries, it will undoubtedly be of interest to our readers to hear about a new departure in power generation, which makes it possible to generate 1 hp.-hour for ¼ of a cent directly out of anthracite, figuring the latter at $5 per ton.

Producer gas power plants are built for generating out of a suitable fuel a mixture of carbon-monoxide and hydrogen, which, if used in gas engines, allows an exceedingly advantageous utilization of the fuel. Up to the present time producer gas has been produced in so-called pressure gas producers by evaporating water in a separate boiler and by leading the steam, mixed with air, by means of a steam jet blower or fan through the glowing fuel, whereby the steam is decomposed to hydrogen and the coal burned to carbon-monoxide. This mixture of combustible gases is lead through a scrubber to a gas-holder, and from there to the engine. It is evident from this description that for generating gas by this method a boiler and a gas-holder is required, which increases considerably the cost of construction and of attendance.

These pressure gas plants are now being superseded by the so-called suction gas producer plants, which are simpler and

cheaper in construction and easy to attend, since no boiler or gas-holder is required. In a suction gas producer plant the boiler is supplanted by an evaporator, which, in small plants, is built on the top of the producer, and in large plants right near the producer in the form of a tubular evaporator. This evaporator is generating the steam required by utilizing the heat of the producer and of the gases. This is of considerable advantage as compared with the old system, as the firing of a separate boiler is dispensed with, and the heat of the gases produced is used for generating the necessary amount of steam.

The heat of the gases, respectively, of the producer is entirely sufficient for furnishing such a quantity of steam as is required for the generation of an effective power gas. The utilization of the fuel in suction gas producers is higher than in pressure producers, and is reaching 80 per cent or more. By leading the steam under the grate the latter is kept cool and clean. The transformation of steam into hydrogen and the formation of carbon-monoxide is taking place so quickly that the producer is always making the amount of gas required, and is able to start suddenly from low to full load.



SUCTION GAS PRODUCER.

As advantages of suction gas producer plants may be claimed:

1. Automatic generation of the gas by the engine.
2. Highest and best utilization of fuel.
3. No boiler and no gas-holder is requred.
4. Can be erected without danger in any convenient place.
5. Easy to start and to run.
6. No scot, no smoke, no odor.
7. No explosion possible.
8. Small floor-space required.

A complete suction gas producer plant consists of a producer, an evaporator, an overflow water-pot, a scrubber and an equalizer (sawdust scrubber). The producer is lined with fire bricks. By the sucking action of the engine a mixture of air and steam is drawn through the burning fuel, whereby the producer gas is generated. There is always only as much gas made as is required by the engine. The producer is provided with a hopper, through which fuel can be filled into the producer without interfering with the working of the engine. The cleaning of the grate may be performed during the regular work. The gas leaving the producer is heating up the evaporator and causes here a formation of steam which goes under the grate together with the necessary amount of air. From the producer the gas goes through the scrubber in which it is cooled and purified from the dust and tar. From the scrubber it goes through a small equalizer.

The Working of the Plant.

Before starting the engine the fuel in the producer has to be heated up by means of a small blower "a", attached to same, until the gas is burning well. For this about ten minutes are required. When this point is reached the hand blower is stopped and the engine started in the usual way.

The engine is now drawing, by her own sucking action, the necessary amount of air and is producing her own power gas. The air is entering at "c" and goes through the evaporator "b." Here it is saturated with steam and the mixture of air and steam is now going through "d" under the grate of the producer, through the fuel, and then through pipe "e" to the scrubber; from here through pipe "e-l" to the equalizing tank "f", which is directly connected with the engine.

The gas-making process continues as long as the engine is moving, but as soon as the engine is stopped the gas-making is also stopped.

Fuel.

Anthracite, charcoal or coke can be used equally well for generating gas in the suction gas producer. It will take, according to the ash content, 1 to 1 1-3 pounds of anthracite or charcoal, or 1 1-3 to 1½ pounds of coke for developing 1 hp.-hour. With anthracite (pea) at $5 per ton, 1 hp. for twenty-four hours will cost from 6 to 8 cents. This is about one-sixth the cost of illuminating gas power (at a price of 75 cents per 1000 cubic feet of illuminating gas) or one-eighth the cost of gasolene (at a price of 16 cents per gallon).

These plants are built by Oskar Nagel, 90 Wall Street, New York City, in units of from 5 to 300 hp.

INDUSTRIAL NOTES

The Lidgerwood Manufacturing Co., of New York City, have issued a very attractive and fully illustrated catalogue on The Lidgerwood Cableway, a hoisting and conveying device employed in the construction of canals, dry docks, dams, locks, filter beds, piers, log handling, open pit mining, quarrying, discharging vessels, etc.

The Abbe Engineering Co., of New York City, have sent us their illustrated catalogue on pulverizers and pebble mill specialties for fine grinding and thorough mixing. This company has now added a new feature to its business, which is a complete testing laboratory, where they have upwards of a dozen of their different mills constantly set up read to work, when prospective buyers desire the machines do their work before purchasing.

PERSONAL.

Dr. Charles A. Doremus has retired from his duties as professor of chemistry at the College of the City of New York. The last work of Dr. Doremus at the college was to help in the designing of its splendid new chemical and electrochemical laboratory. He will now devote all his time to his duties as consulting chemist in developing and perfecting processes, and as expert in patent causes in chemistry and electrochemistry. Dr. Doremus has always been a strong believer in the future of electrochemical methods in chemistry and metallurgy; he was one of the first advocates and founders of the American Electrochemical Society. His offices will be at 55 West Fifty-Third Street, New York City.

Dr. and Mrs. P. L. T. Heroult, after a trip through the United States and Canada, including a visit to the World's Fair, left for France on October 2. Dr. Héroult presented a highly interesting paper before the International Electrical Congress on the electric furnace in the iron and steel industries. A model of his furnace, and samples of pig iron, special steels and various ferro-alloys, made by his process, are exhibited by the Société Electro-Metallurgique Francaise in the Mines & Metallurgy Building of the World's Fair.

DIGEST OF U. S. PATENTS

Prior to July, 1902.

Compiled by Byrnes & Townsend,
Patent Lawyers,
National Union Building, Washington, D. C.

Electrolysis of Molten Sodium Salts.

(*Concluded from page 384.*)

623,693, April 25, 1899, Charles E. Acker, East Orange, N. J.

Produces alkali metal hydroxides from alloys of the alkali metal and lead by injecting steam into the molten alloy and continuously removing the product. The apparatus is a cylindrical pot with a central bell extending nearly to its bottom and having a steam inlet. The vessel is closed by a cover, the depending edge of which dips into an annular recess sealed with molten caustic. Steam forced into the bell escapes below its lower edge and rises through the alloy, oxidizing and hydrating the sodium. The caustic accumulates as a molten layer on the metal, and the hydrogen forces its way out through the seal.

679,997, August 6, 1901, George P. Scholl, Philadelphia, Pa.

Electrolyzes a molten mixture of sodium sulphide and caustic soda, equal parts, with a voltage of 1.2. The suphide only is decomposed and the sulphur combines with the caustic, which is replenished. The process is applicable to other metals and other compounds than hydroxide may be added.

Molten Electrolytes, Miscellaneous.

3,698, August 10, 1844, Arthur Wall, Poplar Blackwall, England.

Purifies iron, steel, copper and other metals by passing electricity through them while molten and solidifying. To treat castings, an electrode of clean wrought-iron is embedded in each end of the sand mold, the circuit being closed by the cast metal. One or more iron wires may be stretched through the mold to initially carry the current.

To treat the metal in smelting furnaces or cupolas, iron rod electrodes are inserted in position to touch the molten metal. To treat metal in a puddling furnace, one iron rod electrode is fixed and the other is movable and has a porcelain handle by which it is stirred through the metal. To carburize iron, wrought-iron bars are heated in a bed of animal charcoal, rosin and white arsenic until converted into blister steel, and electricity is passed through them while they are still red-hot and cooling until their temperature falls to a point where they will retain magnetism. The source of electricity is 8 Grove or 20-30 Smee cells.

28,543, May 29, 1860, George Nock, Pittsburg, Pa.

Refers to the desulphurization of coke by electricity.

86,536, February 2, 1869, Alexander Hamar, Philadelphia, Pa.

Decarburizes cast iron and converts it into steel by passing electricity through the molten iron as it falls from a ladle carrying one electrode onto a cone carrying the other electrode, and by which the iron is sprayed, a blast of air being simultaneously passed upward through the spray.

86,537, February 2, 1869, Alexander Hamar, Philadelphia, Pa.

Same as preceding.

102,146, April 19, 1870, Charles Motier Nes, York, Pa.

Converts pig iron into steel. A mixture of pig, ore and coals is first smelted in a cupola, steel bars connected to a Grove battery of from 6 to 10 cells being inserted in the hearth in position to pass electricity through the molten iron. The iron is then run into an air-tight fire-brick receptacle, in which it is recarburized and subjected to electricity by wires leading from the battery into the metal. Both the cupola and receptacle are insulated by glass.

104,873, June 28, 1870, Charles M. Nes, York, Pa.

Employs electricity "substantially in the manner described" in the preceding patent to facilitate the conversion of Bessemer steel into cast steel by decarburizing and recarburizing the metal.

108,287, October 11, 1870, Charles M. Nes, York, Pa.

Employs electrodes in forge-fires and converters to improve the quality of the steel, the furnaces being insulated by glass.

133,099, November 19, 1872, A. T. Hay, Burlington, Iowa.

Surrounds the stack of a cupola or blast furnace with magnetizing coils located, *e. g.*, at the "zone of heating," "zone of combustion," "zone of reduction," "zone of fusion," and "zone of carburation."

141,132, July 22, 1873, Octave Gauduin, Jean B. J. Mignon and Stanislas H. Rouart, Paris, France.

Coats iron with copper, gunmetal, "yellow copper," aluminium bronze, etc., with or without the use of electricity. Specifically, electrodeposits from a molten bath of copper chloride or fluoride 1 part, cryolite 5-6, and some barium chloride, the anode being an ingot of copper or a copper containing vessel.

242,397, May 31, 1881, W. L. Thompson, Boston, Mass.

Surrounds the lower part of a stack roaster by an ozonizer and forces air through the ozonizer into the ore to remove sulphur and oxidize base metals.

382,183, May 1, 1888, J. Omholt, Gossnitz, Saxe-Altenburg, Germany.

Electrolyzes haloids of sodium, calcium, strontium, magnesium and aluminium. Separate bodies of the molten electrolyte are held in receptacles in the hearth of a reverberatory furnace. The electrodes are horizontal, parallel bars of carbon or metal, with terminals extending through the masonry. Each electrode is covered with an arched hood and short discharge pipes with their edges slightly above the electrolyte extend down through the hearth into horizontal collecting chambers, which are filled with an inert gas.

390,964, October 9, 1888, A. T. Hay, Burlington, Ia.

Similar to 133,099. The stack furnace is divided into several superposed sections, insulated from each other by a layer of fire clay. Each section is surrounded by a magnetizing coil of copper wire insulated by manila paper and sodium silicate, each coil having an independent battery.

422,500, March 4, 1890, H. Y. Castner, London, England.

Purifies double chlorides of aluminium and sodium or potassium from iron by passing the molten salt successively through several heated trough-like porcelain-lined iron vessels, each containing a series of alternate anodes of carbon and cathodes of aluminum, arranged as baffle plates. The current through successive pots is decreased, to correspond to the decreasing contents of iron.